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(54) Title: ALPHA AMYLASE FROM THERMOMYCES LANUGINOSUS

(57) Abstract

A recombinant enzyme is described that is useful for preparing bakery products. The enzyme has the following characteristics: (i)  $\alpha$ -amylase activity over the range from about 60 °C to about 80 °C; (ii) a molecular weight of about 54-60 kDa when measured by SDS-PAGE, or of about 55265 Da +/- 100 Da when measured by mass spectrometry; (iii) a pI value of about 3.7 (on a Pharmacia IEF gel, 3-9); (iv) a pH optimum of from about 5.8 to about 6; (v) a temperature optimum of from about 60 °C to about 70 °C.

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**Alpha amylase from *thermomyc s lanuginosus***

The present invention relates to an  $\alpha$ -amylase enzyme.

5 The present invention also relates to the use of the  $\alpha$ -amylase enzyme in the manufacture of foodstuffs, in particular foodstuff based on starch, and especially a bakery product, such as bread and similar baked products based on wheat flour.

Bread has a limited shelf-life because it physically changes with time. Among other 10 things, the crumb texture becomes firm, this process being generally known as staling. One explanation of the process of staling appears to be that the wheat starch undergoes a process of retrogradation (re-crystallisation) over a period of time, but undoubtedly there are many other factors.

15 It has been shown that the addition of bacterial  $\alpha$ -amylases to bread, and to a lesser extent, fungal and cereal  $\alpha$ -amylases, can retard staling by modifying the gelatinised starch so that retrogradation (recrystallisation) is delayed. For example, see Eliasson, A. and Larssen, K. in *Cereals In Breadmaking - A Molecular Colloidal Approach*, (1993), Marcel Dekker Inc., 351. However, the activity of bacterial amylases is 20 difficult to control during the baking process and in a manner such as to achieve the desired result.

$\alpha$ -Amylases are also traditionally added to the wheat flour used in bread making to improve the baking quality of the flour. Amongst the  $\alpha$ -amylases used for this 25 purpose is the fungal  $\alpha$ -amylase from *Aspergillus oryzae*, Drapon, R. and Godon, B. in *Enzymes And Their Role In Cereal Technology*, (1987), Edited by Kinger, J.E. et al, 281-234, and known as the TAKA-amylase.

However, as a means of delaying the staling process in bread, the TAKA-amylase is 30 far too thermolabile. The gelatinisation of starch (i.e. the melting of starch crystals) starts at about 65°C so that by the time gelatinisation begins much of the TAKA amylase added to the wheat flour will have been inactivated. Bacterial  $\alpha$ -amylases,

- 2 -

on the other hand, are too thermally stable so that they are not properly inactivated by the baking process and may lead to a gummy product - see Leloup *et al* [(1993) Bioconversion of Cereal Products, pp 79-127, B.Godon Ed.].

5 An  $\alpha$ -amylase has been isolated from *Thermomyces lanuginosus* (*T. lanuginosus*) and was found to have a half-life of 10 minutes at 70°C (Enzyme Microbiol. Technol. (1992), 14, 112-116). This  $\alpha$ -amylase was not suggested for use in baking.

10 EP-A-0579360 and WO 90/11352 disclose  $\alpha$ -amylases obtained from *Pyrococcus* and from the bacterium *P. furiosus*, respectively. These  $\alpha$ -amylases were not suggested for use in baking.

15 For optimal baking properties, an  $\alpha$ -amylase should have at least two main criteria. First, the enzyme should be active during the starch gelatinisation stage, which occurs from about 60°C to about 70°C. Second, the enzyme should be inactivated during the baking stage, which occurs from about 80°C to about 100°C. Thus, an  $\alpha$ -amylase with intermediate heat stability will be suitable for baking purposes.

20 The present invention seeks to provide an  $\alpha$ -amylase that can be beneficial for baking and which can be prepared easily and in large amounts.

According to a first aspect of the present invention there is provided a recombinant enzyme having the following characteristics:

25 i.  $\alpha$ -amylase activity over the range from about 60°C to about 80°C;  
ii. a molecular weight of about 54 - 60 kDa when measured by SDS-PAGE, or of about 55265 Da +/- 100 Da when measured by mass spectrometry;  
iii. a pI value of about 3.7 (on a Pharmacia IEF gel, 3-9);  
30 iv. a pH optimum of from about 5.8 to about 6;  
v. a temperature optimum of from about 60°C to about 70°C.

- 3 -

According to a second aspect of the present invention there is provided a recombinant nucleotide sequence comprising the coding nucleotide sequence shown in SEQ. I.D. No. 1, or a variant, homologue or fragment thereof.

5 According to a third aspect of the present invention there is provided a recombinant nucleotide sequence comprising the nucleotide sequence shown as SEQ. I.D. No. 1, or a variant, homologue or fragment thereof.

10 According to a fourth aspect of the present invention there is provided a construct comprising the recombinant nucleotide sequence according to the present invention.

According to a fifth aspect of the present invention there is provided a vector comprising the recombinant nucleotide sequence according to the present invention or the construct according to the present invention.

15 According to a sixth aspect of the present invention there is provided a cell, tissue or organism comprising the recombinant nucleotide sequence according to the present invention or the construct according to the present invention or the vector according to the present invention.

20 According to a seventh aspect of the present invention there is provided a transgenic organism comprising the recombinant nucleotide sequence according to the present invention or the construct according to the present invention or the vector according to the present invention or the cell, tissue or organism according to the present invention.

25 According to an eighth aspect of the present invention there is provided NCIMB deposit No. 40655, NCIMB deposit No. 40656, NCIMB deposit No. 40657 or NCIMB deposit No. 40658.

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- 4 -

According to a ninth aspect of the present invention there is provided a method of preparing a bakery product comprising forming a mixture by contacting a wheat-flour dough with an  $\alpha$ -amylase and baking the mixture, wherein the  $\alpha$ -amylase is a recombinant  $\alpha$ -amylase according to the present invention, or is a recombinant  $\alpha$ -amylase expressed by the nucleotide sequence of the present invention, which may be present in any of the afore-mentioned nucleotide aspects of the present invention.

According to a tenth aspect of the present invention there is provided a bakery product obtained by use of the recombinant  $\alpha$ -amylase according to the present invention, or a recombinant  $\alpha$ -amylase expressed by the nucleotide aspect of the present invention.

According to an eleventh aspect of the present invention there is provided the use of a recombinant  $\alpha$ -amylase having  $\alpha$ -amylase activity over the range from about 60°C to about 80°C in baking.

According to a twelfth aspect of the present invention there is provided a method of preparing a foodstuff comprising forming a mixture by contacting starch or a starch based ingredient with an  $\alpha$ -amylase and optionally processing the mixture, wherein the  $\alpha$ -amylase is a recombinant  $\alpha$ -amylase as defined above or is a recombinant  $\alpha$ -amylase expressed by the nucleotide aspect of the present invention.

According to a thirteenth aspect of the present invention there is provided a foodstuff obtained by use of an  $\alpha$ -amylase enzyme wherein the enzyme is a recombinant  $\alpha$ -amylase as defined above or is a recombinant  $\alpha$ -amylase expressed by the nucleotide aspect of the present invention.

According to a fourteenth aspect of the present invention there is provided the use of a recombinant  $\alpha$ -amylase having  $\alpha$ -amylase activity over the range from about 60°C to about 80°C in preparing a foodstuff.

- 5 -

Other aspects of the present invention include inserting the recombinant  $\alpha$ -amylase nucleotide sequence of the present invention into a suitable vector and/or transforming a suitable host organism with the recombinant  $\alpha$ -amylase nucleotide sequence of the present invention and/or expressing that recombinant  $\alpha$ -amylase nucleotide sequence 5 gene within the host and/or collecting the expressed recombinant  $\alpha$ -amylase and/or isolating the recombinant  $\alpha$ -amylase.

Further aspects of the present invention include:

- 10 1) other than when forming part of the natural genome, a recombinant nucleotide sequence, which may be either an RNA or DNA sequence, that encodes for a recombinant protein according to the first aspect of the present invention, and in particular the DNA sequence shown in SEQ I.D. No. 1;
- 15 2) a nucleotide sequence that is functionally equivalent to the DNA sequence shown in SEQ I.D. No. 1, that is to say a DNA sequence showing substantial (at least 90%) homology (similarity) therewith and coding for a recombinant  $\alpha$ -amylase having the same properties of the recombinant  $\alpha$ -amylase having the amino acid sequence as set out in SEQ I.D. No. 1, but differing from the DNA sequence of SEQ I.D. No. 1 by 20 virtue only of the degeneracy of the genetic code;
- 25 3) a recombinant nucleotide sequence that is complementary to the DNA sequence shown in SEQ I.D. No. 1, and the equivalent sequence mentioned in 2);
- 30 4) a vector containing the sequences identified in 1), 2), and 3) and especially expression vectors containing that sequence downstream from a suitable promoter sequence capable of expressing the recombinant  $\alpha$ -amylase when inserted in a suitable host;
- 35 5) a transformant when transformed with a vector according to 4), and especially a transformant transformed with an expression vector and capable of expressing the recombinant  $\alpha$ -amylase, and especially an *Aspergillus niger* transformant; and

- 6 -

vi) a method for the production of a recombinant  $\alpha$ -amylase according to the present invention which comprises culturing a transformant according to v) and recovering from the culture the recombinant  $\alpha$ -amylase expressed in the culture by the transformant.

5

Preferrably the enzyme comprises an N-terminal sequence shown as SEQ. I.D. No. 11.

10 Preferably the enzyme comprises the sequence shown as SEQ. I.D. No. 1 or SEQ. I.D. No. 2, or a variant, homologue or fragment thereof.

Preferably the enzyme is expressed by a nucleotide sequence comprising the coding sequence shown in SEQ. I.D. No. 1, or a variant, homologue or fragment thereof.

15 Preferably the enzyme is expressed by a nucleotide sequence comprising the nucleotide sequence shown as SEQ. I.D. No. 1, or a variant, homologue or fragment thereof.

Preferably the enzyme is obtained or obtainable from *T. lanuginosus*.

20

Preferably the enzyme is expressed by a member of the *Aspergillus* family.

Preferably the enzyme is expressed by *Aspergillus niger*.

25 Preferably the enzyme is obtainable from any one of NCIMB deposit No. 40655, NCIMB deposit No. 40656, NCIMB deposit No. 40657 and NCIMB deposit No. 40658.

30 Preferably, the transgenic organism is a filamentous fungi, preferably an *Aspergillus* fungus, more preferably *Aspergillus niger*.

- 7 -

Preferably, in the method, the recombinant  $\alpha$ -amylase is incorporated into the dough in an amount sufficient to provide from 50 to 400 units of  $\alpha$ -amylase activity per kg of wheat flour used to form the dough.

5 Preferably, in the method, the recombinant  $\alpha$ -amylase is incorporated into the mixture in an amount sufficient to provide from 50 to 400 units of  $\alpha$ -amylase activity per kg of starch or starch based ingredient to form the mixture.

Preferably, in the method, the foodstuff or bakery product is bread.

10

Preferably, in the use, the recombinant  $\alpha$ -amylase is a recombinant  $\alpha$ -amylase according to the first aspect of the present invention or is a recombinant  $\alpha$ -amylase expressed by the nucleotide aspects of the present invention.

15 In a first highly preferred embodiment, the recombinant  $\alpha$ -amylase enzyme of the present invention has a protein sequence as set out in SEQ.I.D. No. 1 and SEQ.I.D. No. 2.

In a second highly preferred embodiment, the recombinant  $\alpha$ -amylase enzyme of the 20 present invention is coded by the nucleotide sequence as set out in SEQ.I.D. No. 1.

In a third highly preferred embodiment, the recombinant nucleotide sequence is the nucleotide sequence as set out in SEQ.I.D. No. 1.

25 One of the advantages of the recombinant enzyme of the present invention is that when it is used in baking it improves the shelf-life of bread and other products made from a wheat-flour dough. In this regard, it improves the resistance of bread, and other products made from a wheat-flour dough, to staling. In particular, the recombinant  $\alpha$ -amylase has a beneficial thermal activity profile for use in baking.

30

In addition, the recombinant enzyme of the present invention can be beneficially used in combination with other enzymes useful in the preparation of bakery products.

- 8 -

Other advantages are that the recombinant enzyme can be prepared easily, reliably and cheaply and in large amounts. For example, expressing the gene in *Aspergillus niger* has the advantage that purification and recovery procedures of the recombinant  $\alpha$ -amylase are simpler. Moreover, expression in *Aspergillus niger* would obviate the 5 need to remove the intron sequences prior to transformation of that host organism with the recombinant nucleotide sequence of the present invention.

The term "recombinant" is used in its normal sense. For example, the term "recombinant enzyme" does not include an enzyme when prepared by expression of 10 the genomic nucleotide sequence coding for the enzyme when that nucleotide sequence is in its natural environment. Thus, the term covers the enzyme when prepared by expression of a recombinant nucleotide sequence coding for the enzyme when that nucleotide sequence is not in the natural environment for the genomic nucleotide coding sequence. Thus the term "recombinant nucleotide" includes 15 recombinant DNA and recombinant RNA. Preferably it means recombinant DNA, and in some instances it preferably means cDNA.

The recombinant enzyme can be used on its own or in combination with one or more other enzymes.

20

The terms "variant" or "homologue" or "fragment" include any substitution of, variation of, modification of, replacement of, deletion of or addition of one (or more) nucleic acid or amino acid from or to a respective sequence providing the resultant sequence has the respective ability to code for or act as an enzyme according to the 25 present invention, preferably having at least the same activity of the enzyme comprising the sequence shown as the sequence listing SEQ. I.D. No. 1. In particular, the term "homologue" covers homology with respect to similarity of structure and/or similarity of function providing the resultant nucleotide sequence has the ability to code for an enzyme according to the present invention. With respect 30 to sequence homology, preferably there is more than 80% homology, more preferably at least 85% homology, more preferably at least 90% homology, even more preferably at least 95% homology, more preferably at least 98% homology. The

- 9 -

expressions also cover any codon replacement or substitution with another codon coding for the same amino acid or any addition or removal thereof providing the resultant enzyme has  $\alpha$ -amylase activity. Thus, the present invention also covers a modified nucleotide sequence in which at least one nucleotide has been deleted, 5 substituted or modified or in which at least one additional nucleotide has been inserted so as to encode an enzyme having the activity of an  $\alpha$ -amylase, preferably having an increased  $\alpha$ -amylase activity. The above terms are also synonymous with allelic variations of the sequences.

10 The term "complementary" means that the present invention also covers recombinant nucleotide sequences that can hybridise to the recombinant nucleotide sequences.

The term "construct" - which is synonymous with terms such as "conjugate", "cassette" and "hybrid" - includes the nucleotide sequence according to the present 15 invention directly or indirectly attached to the promoter. An example of an indirect attachment is the provision of a suitable spacer group such as an intron sequence, such as the *Sh1*-intron or the ADH intron, intermediate the promoter and the nucleotide sequence of the present invention. The same is true for the term "fused" in relation to the present invention which includes direct or indirect attachment. The 20 terms do not cover the natural combination of the wild type  $\alpha$ -amylase gene ordinarily associated with the wild type gene promoter and the wild type promoter and when they are both in their natural environment.

The construct may even contain or express a marker which allows for the selection 25 of the genetic construct in, for example, a fungus or a plant cell into which it has been transferred. Various markers exist which may be used in, for example, plants - such as mannose. Other examples of markers include those that provide for antibiotic resistance - e.g. resistance to G418, hygromycin, bleomycin, kanamycin and gentamycin.

30 The construct of the present invention preferably comprises a promoter.

- 10 -

The term "promoter" is used in the normal sense of the art, e.g. an RNA polymerase binding site in the Jacob-Monod theory of gene expression. Examples of suitable promoters are those that can direct efficient expression of the nucleotide sequence of the present invention and/or in a specific type of cell. The promoter could

5     additionally include conserved regions such as a Pribnow Box or a TATA box. The promoters may even contain other sequences to affect (such as to maintain, enhance, decrease) the levels of expression of the nucleotide sequence of the present invention.

For example, suitable examples of such sequences include the *Sh1*-intron or an ADH intron. Other sequences include inducible elements - such as temperature, chemical,

10    light or stress inducible elements. Also, suitable elements to enhance transcription or translation may be present. An example of the latter element is the TMV 5' leader sequence (see Sleat Gene 217 [1987] 217-225; and Dawson Plant Mol. Biol. 23 [1993] 97).

15    The terms "obtained" and "obtainable" from *T. lanuginosus* include products obtained directly from cultures of transformed *T. lanuginosus* and products obtained by expression of a recombinant  $\alpha$ -amylase gene of the present invention obtainable from *T. lanuginosus* when the gene is in another cellular organism. Preferably, the terms cover expression of the recombinant  $\alpha$ -amylase gene of the present invention in

20    another cellular organism, preferably *Aspergillus niger*.

The term "vector" includes an expression vector and a transformation vector. The term "expression vector" means a construct capable of *in vivo* or *in vitro* expression. The term "transformation vector" means a construct capable of being transferred from

25    one species to another - such as from an *E. Coli* plasmid to a fungus or a plant cell, or from an *Agrobacterium* to a plant cell.

The terms "cell", "tissue" and "organ" include cell, tissue and organ *per se* and when within an organism.

- 11 -

The term "organism" in relation to the present invention includes any organism that could comprise the recombinant nucleotide sequence coding for the enzyme according to the present invention and/or products obtained therefrom, and/or wherein the recombinant nucleotide sequence according to the present invention can be expressed 5 when present in the organism. Preferably the organism is an  $\alpha$ -amylase producing organism such as any one of a plant, algae, fungi, yeast and bacteria, as well as cell lines thereof. Preferably the organism is a filamentous fungus, preferably of the genus *Aspergillus*, more preferably *Aspergillus niger*.

- 10 The term "transgenic organism" in relation to the present invention includes any organism that comprises the recombinant nucleotide sequence coding for the enzyme according to the present invention and/or products obtained therefrom, and/or wherein the recombinant nucleotide sequence according to the present invention can be expressed within the organism. Preferably the recombinant nucleotide sequence is 15 incorporated in the genome of the organism. Preferably the transgenic organism is a filamentous fungus, preferably of the genus *Aspergillus*, more preferably *Aspergillus niger*.

- 20 If the organism can not naturally splice intron regions post expression then a pre-transformation step may be necessary wherein any intron sections are removed.

- 25 The host organism can be a prokaryotic or a eukaryotic organism. Examples of suitable prokaryotic hosts include *E. coli* and *Bacillus subtilis*. Teachings on the transformation of prokaryotic hosts is well documented in the art, for example see Sambrook *et al* (Sambrook *et al.* in Molecular Cloning: A Laboratory Manual, 2nd edition, 1989, Cold Spring Harbor Laboratory Press). If a prokaryotic host is used then the recombinant nucleotide sequence of the present invention may need to be suitably modified before transformation - such as by removal of introns.
- 30 As mentioned above, a preferred host organism is of the genus *Aspergillus*, such as *Aspergillus niger*.

- 12 -

The transgenic *Aspergillus* according to the present invention can be prepared by following the teachings of Rambosek, J. and Leach, J. 1987 (Recombinant DNA in filamentous fungi: Progress and Prospects. CRC Crit. Rev. Biotechnol. 6:357-393), Davis R.W. 1994 (Heterologous gene expression and protein secretion in *Aspergillus*.

5 In: Martinelli S.D., Kinghorn J.R. ( Editors) *Aspergillus*: 50 years on. Progress in industrial microbiology vol 29. Elsevier Amsterdam 1994. pp 525-560), Ballance, D.J. 1991 (Transformation systems for Filamentous Fungi and an Overview of Fungal Gene structure. In: Leong, S.A., Berka R.M. (Editors) Molecular Industrial Mycology. Systems and Applications for Filamentous Fungi. Marcel Dekker Inc.

10 New York 1991. pp 1-29) and Turner G. 1994 (Vectors for genetic manipulation. In: Martinelli S.D., Kinghorn J.R. ( Editors) *Aspergillus*: 50 years on. Progress in industrial microbiology vol 29. Elsevier Amsterdam 1994. pp. 641-666). However, the following commentary provides a summary of those teachings for producing transgenic *Aspergillus* according to the present invention.

15

Filamentous fungi have been widely used in industry for production of organic compounds and enzymes. Traditional Japanese koji and soy fermentations have used *Aspergillus* sp for hundreds of years. In this century *Aspergillus niger* has been used for production of organic acids particular citric acid and for production of various enzymes for use in industry.

20

There are two major reasons for that filamentous fungi have been so widely used in industry. First filamentous fungi can produce high amounts of extracellular products, for example enzymes and organic compounds such as antibiotics or organic acids.

25 Second filamentous fungi can grow on low cost substrates such as grains, bran, beet pulp etc. The same reasons have made filamentous fungi attractive organisms as hosts for heterologous gene expression according to the present invention.

30 In order to prepare the transgenic *Aspergillus*, expression constructs are prepared by inserting the recombinant nucleotide sequence of the present invention into a construct designed for expression in filamentous fungi. In this regard, several types of constructs used for heterologous gene expression have been developed. The

- 13 -

constructs will contain a promoter which is active in fungi. Examples of promoters include a fungal promoter for a highly expressed extracellular enzyme, such as an glucoamylase promoter or an  $\alpha$ -amylase promoter. The recombinant nucleotide sequence of the present invention can be fused to a signal sequence which directs the 5 enzyme encoded by the nucleotide sequence to be secreted. Usually a signal sequence of fungal origin is used. A terminator active in fungi ends the expression system.

Another type of expression system has been developed in fungi where the recombinant nucleotide sequence of the present invention is fused to a smaller or a 10 larger part of a fungal gene encoding a stable protein. This can stabilize the protein encoded by the recombinant nucleotide sequence of the present invention. In such a system a cleavage site, recognized by a specific protease, can be introduced between the fungal protein and the enzyme encoded by the recombinant nucleotide sequence of the present invention, so the produced fusion protein can be cleaved at this position 15 by the specific protease thus liberating the protein or enzyme encoded by the recombinant nucleotide sequence of the present invention. By way of example, one can introduce a site which is recognized by a KEX-2 like peptidase found in at least some *Aspergilli*. Such a fusion leads to cleavage *in vivo* resulting in protection of the recombinant enzyme and production of the recombinant enzyme and not a larger 20 fusion protein or enzyme.

Heterologous expression in *Aspergillus* has been reported for several genes coding for bacterial, fungal, vertebrate and plant proteins or enzymes. The proteins can be deposited intracellularly if the recombinant nucleotide sequence of the present 25 invention is not fused to a signal sequence. Such proteins or enzymes will accumulate in the cytoplasm and will usually not be glycosylated which can be an advantage for some bacterial proteins or enzymes. If the recombinant nucleotide sequence of the present invention is equipped with a signal sequence the enzyme will accumulate extracellularly.

- 14 -

With regard to product stability and host strain modifications, some heterologous proteins or enzymes are not very stable when they are secreted into the culture fluid of fungi. Most fungi produce several extracellular proteases which degrade heterologous proteins or enzymes. To avoid this problem special fungal strains with 5 reduced protease production have been used as hosts for heterologous production.

For the transformation of filamentous fungi, several transformation protocols have been developed for many filamentous fungi. Many of them are based on preparation of protoplasts and introduction of DNA into the protoplasts using PEG and  $\text{Ca}^{2+}$  ions. 10 The transformed protoplasts then regenerate and the transformed fungi are selected using various selective markers. Among the markers used for transformation are a number of auxotrophic markers such as *argB*, *trpC*, *niaD* and *pyrG*, antibiotic resistance markers such as benomyl resistance, hygromycin resistance and phleomycin resistance. A very common used transformation marker is the *amdS* gene of *A. nidulans* which in high copy number allows the fungus to grow with acrylamide as 15 the sole nitrogen source.

In another embodiment the transgenic organism can be a yeast. In this regard, yeast have been widely used as a vehicle for heterologous gene expression. The species 20 *Saccharomyces cerevisiae* has a long history of industrial use, including use for heterologous gene expression. Expression of heterologous genes in *Saccharomyces cerevisiae* has been reviewed by Goodey *et al* (1987, Yeast Biotechnology, D R Berry *et al*, eds, pp 401-429, Allen and Unwin, London) and by King *et al* (1989, Molecular and Cell Biology of Yeasts, E F Walton and G T Yarrington, eds, pp 107- 25 133, Blackie, Glasgow).

For several reasons *Saccharomyces cerevisiae* is well suited for heterologous gene expression. First, it is non-pathogenic to humans and it is incapable of producing certain endotoxins. Second, it has a long history of safe use following centuries of 30 commercial exploitation for various purposes. This has led to wide public acceptability.

- 15 -

Third, the extensive commercial use and research devoted to the organism has resulted in a wealth of knowledge about the genetics and physiology as well as large-scale fermentation characteristics of *Saccharomyces cerevisiae*.

5 An additional advantage is that yeasts are capable of post-translational modifications of proteins and thereby have the potential for glycosylation and/or secretion of heterologous gene products into the growth medium.

10 A review of the principles of heterologous gene expression in *Saccharomyces cerevisiae* and secretion of gene products is given by E Hinchcliffe E Kenny (1993, "Yeast as a vehicle for the expression of heterologous genes", Yeasts, Vol 5, Anthony H Rose and J Stuart Harrison, eds, 2nd edition, Academic Press Ltd.).

15 Also, yeasts are known to secrete very few proteins into the culture medium. This makes yeast a very attractive host for expression of heterologous genes, since secretable gene products can easily be recovered and purified.

20 Several types of yeast vectors are available, including integrative vectors, which require recombination with the host genome for their maintenance, and autonomously replicating plasmid vectors.

25 In order to prepare the transgenic *Saccharomyces*, expression constructs are prepared by inserting the recombinant nucleotide sequence of the present invention into a construct designed for expression in yeast. Several types of constructs used for heterologous expression have been developed. The constructs contain a promoter active in yeast fused to the recombinant nucleotide sequence of the present invention, usually a promoter of yeast origin, such as the GAL1 promoter, is used. The recombinant nucleotide sequence of the present invention can be fused to a signal sequence which directs the enzyme encoded by the nucleotide sequence to be secreted. Usually a signal sequence of yeast origin, such as the sequence encoding the SUC2 signal peptide, is used. A terminator active in yeast ends the expression system.

- 16 -

For expression in yeast, it may be advantageous to remove some or all of the intron or intron sequences.

Heterologous expression in yeast has been reported for several genes. The gene 5 products can be glycosylated which is advantageous for some enzymes intended for specific application where heat tolerance is desirable. The protein or enzyme can be deposited intracellularly if the recombinant nucleotide sequence of the present invention is not fused to a signal sequence, or they can be secreted extracellularly if the recombinant nucleotide sequence of the present invention is equipped with a signal 10 sequence.

For the transformation of yeast several transformation protocols have been developed. The transgenic *Saccharomyces* according to the present invention can be prepared by following the teachings of Hinnen *et al* (1978, Proceedings of the National Academy 15 of Sciences of the USA 75, 1929); Beggs, J D (1978, Nature, London, 275, 104); and Ito, H *et al* (1983, J Bacteriology 153, 163-168).

The transformed yeast cells are selected using various selective markers. Among the markers used for transformation are a number of auxotrophic markers such as LEU2, 20 HIS4 and TRP1, and dominant antibiotic resistance markers such as aminoglycoside antibiotic markers, eg G418.

The present invention relates to the manufacture of a foodstuff. The foodstuff may be based on starch and can be, for example, any one of bread, pasta, noodles etc.

25 However, in a preferred aspect, the present invention provides a method of improving the shelf-life and resistance to staling of bread and other products made from wheat flour dough which comprises incorporating into the dough an  $\alpha$ -amylase according to the first aspect of the present invention. Typically, the recombinant  $\alpha$ -amylase is 30 incorporated into the dough in an amount sufficient to provide from 50 to 400 units of  $\alpha$ -amylase activity per kg of wheat flour used to form the dough.

- 17 -

The recombinant  $\alpha$ -amylase can be added to the dough at any convenient time during the mixing process, and may be used in conjunction with other enzymes, such as enzymes added as dough improvers, which may also be added in the conventional manner.

5

Thus, the recombinant  $\alpha$ -amylase enzyme of the present invention may be added in combination with other enzymes or chemical additives, such as emulsifiers, rheology modifiers, stabilisers, surfactants, preservatives, flavourings, colourings etc.

10 Typically, the other ingredients and procedures used to form the dough and to bake the dough will be conventional and can be found in any relevant textbook.

A number of plasmids have been prepared in accordance with the present invention by adaptation, including *in vivo* excision, of ZAPII phage. These plasmids, which 15 have been called pAMYA-1, pAMYA-2, pAMYA-3 and pAMYA-5, contain the  $\alpha$ -amylase gene of the present invention. pAMYA-1 is 8.48 Kb in size, pAMYA-2 is 7.98 Kb in size, pAMYA-3 is 9.98 Kb in size and pAMYA-5 is 10.48 Kb in size.

20 *E. coli* containing these plasmids have been deposited with the National Collections of Industrial and Marine Bacteria (NCIMB), 23 St. Machar Drive, Aberdeen AB2 1RY, United Kingdom, on 23 June 1994 under the deposit numbers:

pAMYA-1: NCIMB 40655

25 pAMYA-2: NCIMB 40656

pAMYA-3: NCIMB 40657

pAMYA-5: NCIMB 40658

30 A further plasmid has been prepared in accordance with the present invention. This plasmid has been called pPR28. This plasmid also contains the  $\alpha$ -amylase gene of the present invention. This plasmid has 6573 base pairs.

- 18 -

The present invention will now be described only by way of examples, in which reference shall be made to the following Figures:

Figure 1 is a restriction map of plasmid pAMYA-1;

5

Figure 2 is a restriction map of plasmid pAMYA-2;

Figure 3 is a restriction map of plasmid pAMYA-3;

10 Figure 4 is a restriction map of plasmid pAMYA-5;

Figure 5 is a restriction map of plasmid pPR28;

Figure 6 is a graph used to determine a pH optimum;

15

Figure 7 is a graph used to determine a temperature optimum;

Figure 8 contains plots of a starch degradation study; and

20 Figure 9 contains plots of a baking study.

In the following experiments,  $\alpha$ -amylase activity is determined by use of the following protocol.

25 Protocol For Measurement of  $\alpha$ -Amylase Activity

$\alpha$ -amylase activity was analysed by determining the degree of hydrolysis of a standard starch solution (modification of method described by Sandstedt et al. 1939). The reaction mixture consisted of 2.5 ml of a 2% (w/v) solution of soluble wheat starch 30 in 0.1 M sodium acetate buffer, 20 mM  $\text{CaCl}_2$  (pH 4.8) and 0.5 ml of an enzyme solution. After 12, 14, 16, 18 and 20 minutes 0.5 ml extracts of the reaction mixture were transferred to 2.5 mls of a  $\text{I}_2\text{-KI}$  solution (0.7 mM  $\text{I}_2$  and 241 mM KI).

- 19 -

The absorbance of the blue-coloured complex between starch and I<sub>2</sub>-KI was then measured at 620nm against water. The time needed to reach an absorbance of 0.48 was determined and used to calculate enzyme activity:

5

$$\text{Activity} = \frac{0.1 \times 60 \times 1000 \text{ FAU/g}}{A \times T}$$

A = enzyme dilution (mg enzyme/ml solution)

T = time (min) necessary to reach an absorbance of 0.48.

10 1 Fungal Amylase Unit (FAU) is the quantity of enzyme which will dextrinise the standard starch solution at a rate of 1 g per hour at 40°C.

15 During purification, amylase activity was estimated by adding 25-100µl of the enzyme solution to 1 ml of the standard starch solution at 50°C and transferring 0.5 ml of the reaction mixture to 2.5 ml I<sub>2</sub> -KI solution after 5-10 minutes. Absorbance at 620 nm of the starch-iodine solution was used as an arbitrary activity unit.

1. Construction of *T. lanuginosus* genomic library

20 1.1. Source Organism

The fungus *Thermomyces lanuginosus* was used as the source organism to generate DNA for a genomic library for subsequent studies and procedures. The *Thermomyces lanuginosus* used was strain CBS 224.63 obtained from Centraalbureau voor Schimmelcultures, Delft (CBS). A sample of this strain was grown on YPS agar plates at 40°C (yeast extract 4 g/l, wheat starch 15 g/l, K<sub>2</sub>HPO<sub>4</sub> 1 g/l, MgSO<sub>4</sub> 0.5 g/l and agar 20 g/l).

- 20 -

1.2. DNA extraction

1g of frozen *T. lanuginosus* mycelium was ground in a mortar under liquid nitrogen.

Following evaporation of the nitrogen cover, the ground mycelium was extracted with

5 15ml of an extraction buffer (100mM Tris-HCl, pH 8.0, 0.50mM EDTA, 500mM NaCl, 10mM  $\beta$ -mercaptoethanol) containing 1ml 20% sodium dodecyl sulphate.

After incubation at 65°C for 10 min. 5ml 5M KAc, pH 5.0, was added and the mixture further incubated, after mixing, on ice for 20 mins. The mixture was then

10 centrifuged for 20 mins. and the supernatant mixed with 0.6 vol. isopropanol to

precipitate the extracted DNA. After further centrifuging for 15 mins. the DNA pellet was dissolved in 0.7 ml TE (10mM Tris, HCl pH 8.0, 1mM EDTA) and precipitated with 75  $\mu$ l 3M NaAc, pH 4.8, and 500  $\mu$ l isopropanol.

After centrifuging the pellet was washed with 70% ETOH and dried under vacuum.

15 The DNA was dissolved in 200  $\mu$ l TE and stored at -20°C.

1.3 DNA digestion and cloning

40  $\mu$ g of the DNA prepared as in 1.2 was digested with 1 U Sau3A in a 500  $\mu$ l

20 volume. 125  $\mu$ l digests were removed after 5, 10, 15 and 20 minutes. Using the 10 and 15 minute digests, the digested DNA was precipitated, dissolved in 20  $\mu$ l water,

mixed with a 50-fold excess of a double stranded DNA adapter having the sequences shown as SEQ I.D. No. 3 and SEQ I.D. No. 4 which has Sau3A and EcoRI

overhangs at either end and two internal restriction sites, and ligated with T4 ligase

25 overnight.

The adaptor can be prepared by annealing equal amounts of the nucleotide sequence shown as SEQ. I.D. No. 3 phosphorylated with T4 polynucleotide kinase and the nucleotide sequence shown as SEQ. I.D. No. 4.

30

After ligation, T4 ligase activity was destroyed by heating for 15 min. at 65°C. The fragments were then phosphorylated with T4 polynucleotide kinase.

- 21 -

The two separate DNA preparations were run on a 1.0% preparative agarose gel and the DNA fragments in the size range 5-10kb were recovered and combined.

150 ng of the combined 5-10kb fragments were then mixed with 1 $\mu$ g of an EcoRI 5 predigested and dephosphorylated  $\lambda$ ZAPII vector (Stratagene #236211) and ligated. The ligated vectors were packed in vitro with Gigapack II Gold packing extracts (Stratagene #200214), and the titre determined.

10 The resultant library contained 300,000 independent phages of which about 95% contained inserts.

2. Construction of a *T. lanuginosus* DNA probe.

2.1 Construction of PCR Primers.

15 By comparisons of the known and published protein sequences of the  $\alpha$ -amylase genes from *Schwanniomyces occidentalis*, *Saccharomycopsis fibuligera* and *Aspergillus oryzae* (Swiss protein release 24 database) two conserved regions of the  $\alpha$ -amylase gene were identified, being respectively the sequences:

20 Met-Glu-Phe-Thr-Ala-Ile-Trp-Ile  
M G P T A I W I

and

25 Tyr-Thr-Cys-Pro-Tyr-Gln-Asn  
Y T C P Y Q N

Corresponding oligonucleotides were then synthesised for each of the possible DNA sequences encoding for those two sequences, taking the degeneracy of the genetic code into account, and for use as degenerate primers in the subsequent PCR 30 amplification of genetic DNA from *T. lanuginosus*. Collectively those degenerate primers are represented by the sequences SEQ I.D. No. 5 (Primer 1) and SEQ I.D. No. 6 (Primer 2).

- 22 -

2.2 PCR Cloning of the *T. lanuginosus*  $\alpha$ -amylase gene

1  $\mu$ g of *T. lanuginosus* DNA in a 100  $\mu$ l volume was amplified by PCR using 100 pmol of each of the Primers 1 and 2 according to the following programme:

5

	STEP 1	97°C	10 min.
	STEP 2	60°C	10 min., polymerase added
	STEP 3	94°C	1 min
	STEP 4	50°C	2 min
10	STEP 5	72°C	2 min
	STEP 6	5°C	indefinite

STEPS 3-5 were repeated for 40 cycles.

15 The reaction produced a ca. 800nt fragment which was cloned in pT7-Blue (Novagen #69829-1). Both ends of the fragment were sequenced using a commercial sequencing kit (USB: Sequenase) using a universal primer and a T7 primer.

20 The determined DNA sequences and the deduced amino acid sequences are set out herein as SEQ I.D. Nos. 7 and 8, and SEQ I.D. Nos. 9 and 10.

3. Isolation of *T. lanuginosus*  $\alpha$ -amylase gene

25 3.1 2 x 30,000 independent clones of the *T. lanuginosus* gene library were plated on 22 x 22 NZY plates (per liter 5g NaCl, 2g MgSO<sub>4</sub>.7H<sub>2</sub>O, 5g Yeast extract, 10g casein hydrolysate, 20g agar, pH 7.5) and plaques obtained. Two replicas of each plate were made on Hybond N membranes (Amersham) and treated according to manufacturer's instructions.

30 3.2 The *T. lanuginosus*  $\alpha$ -amylase gene fragment obtained as in 2.1 above was labelled with  $\alpha$ -<sup>32</sup>P-dCTP using a "Prime-It" random primer labelling kit (Stratagene #300385) and used to probe the membranes obtained as in 3.1. After 24 hours

- 23 -

hybridisation period, the membranes were washed according to the manufacturer's instructions, autoradiographed, and the positive plaques isolated. For this purpose, a positive plaque was declared only if it hybridised to the probe on both membranes.

5 Plaques containing the full length gene were identified. Phages were extracted from the isolated plaques and purified by plating on small NYZ plates and repeating the plaque lift and hybridisations. The purified clones were sub-cloned *in vivo* by the ExAssist system (Stratagene #200253). The resulting plasmids with the full length  $\alpha$ -amylase gene have been named pAMYA 1-3 and 5, and their restriction maps are  
10 shown in Figures 1 - 4.

4. Sequencing of the *T. lanuginosus*  $\alpha$ -amylase gene

4.1 The *T. lanuginosus* gene was sequenced using an ALF (Pharmacia) sequencer.  
15 The complete sequence, which is shown as SEQ I.D. No. 1, comprises eight introns and nine exons.

5. Expression of recombinant  $\alpha$ -amylase

20 5.1 **Transformation**

An *Aspergillus niger* strain, 3M43 (Danisco Ingredients strain collection) was transformed with a construct containing the promoter and the terminator of the xylanase-A gene from *A. niger* (*xlnA*) and the structural gene for amylase, *amyA*, from *T. lanuginosus*. The resultant plasmid is pPR28 is shown in Figure 5.  
25

The *xylA* gene has been described by Graaff et al. (de Graaff, L.H. et al. (1994) Molecular Microbiology 12(3), 479-490). The xylanase-promoter is a 427 bp BspHI fragment ending immediately before the ATG start codon of *xlnA*. A 1079 bp 30 BamHI-XbaI fragment contains the *xlnA* terminator. This fragment starts 64 bp downstream of the translation stop codon of the *xlnA* gene.

- 24 -

A 2106 bp, SacI-Ecl136II fragment of the *amyA* gene contains the protein coding region. This fragment starts 21 bp before the *amyA* start codon and ends 68 bp after the stop codon.

5 The fragments were assembled in pBluescript II SK+ (Stratagene) which was transformed into *A. niger* using a co-transformation procedure (Werners, K. et al. (1987), Molecular and General Genetics 209, 71-77).

### 5.2 Purification of the transgenic $\alpha$ -amylase

10

The transformants were grown in shake flasks (250 ml with 100 ml substrate) in 100 mM MES, pH 5.5 with 2% wheat bran, 2% beet pulp and 0.2% KNO<sub>3</sub>. After 6 days' growth a high  $\alpha$ -amylase activity was found in the cultures of the transformants whereas the untransformed control did not produce amylase.

15

The amylolytic activity was purified as follows: 20 ml of filtered culture material was desalted on PD10 columns (Pharmacia) equilibrated with 20 mM triethanolamine, pH 7.3. 30 ml of the desalted material was applied to an anion exchange column, Q-Sepharose Fast Flow (21 x 2.5 cm, flow 1.5 ml/min, Pharmacia) equilibrated with

20

20 mM triethanolamine, pH 7.3. A NaCl gradient was applied by adding triethanolamine, pH 7.3 with 1 M NaCl (buffer B) as follows: 0 - 25% buffer B in 300 min. and thereafter 25 - 50% buffer B in 700 min. Fractions of 7.5 ml were collected.

25

The  $\alpha$ -amylase containing fractions were pooled (total volume 72 ml) and concentrated to a volume of 10 ml. This sample was loaded onto a gel filtration column, Superdex G75 HiLoad (60 x 2.5 cm) equilibrated with 50 mM sodium acetate buffer containing 0.1 M NaCl, pH 5.8. Protein was eluted with a flow of 1.66 ml/min and fractions of 3.3 ml were collected. Samples of  $\alpha$ -amylase containing fractions were analysed by SDS-PAGE on a 4-12% Tris-glycine gel. The  $\alpha$ -amylase containing fractions gave a broad band at 54 - 60 kDa. The  $\alpha$ -amylase containing fractions were pooled and frozen for further analysis.

- 25 -

### 5.3 Characterization of the recombinant $\alpha$ -amylase

#### 5.3.1 N-terminal Sequence

5 The N-terminal of the purified  $\alpha$ -amylase was determined according to conventional procedures (Matsudaira, P.: A Practical Guide to Protein and Peptide Purification for Microsequencing. Second Edition. Academic Press, San Diego 1993) and was found to have the following sequence:

10 A T P D E W K A Q S

The sequence, which is identical to the amino acid sequence (amino acids number 1 to 10) in SEQ I.D. No. 1, is shown as SEQ I.D. No. 11. This confirms that the purified  $\alpha$ -amylase is derived from the introduced *Thermomyces lanuginosus*  $\alpha$ -amylase gene.

#### 5.3.2 Molecular weight

As mentioned above, the MW of the purified  $\alpha$ -amylase on a Tris-glycine gel was 20 determined to be 54 - 60 kDa. The MW was 55265 +/- 100 Da when determined by mass spectrometry. Specific colouring of the gel showed that the  $\alpha$ -amylase is a glycoprotein which was also confirmed by mass spectrometry.

The MW is 51.737kDa when calculated from the amino acid sequence and the 25 enzyme probably has two N-glycosylated sites.

#### 5.3.3 pI

pI of the  $\alpha$ -amylase was determined by use of a Pharmacia IEF gel, 3-9, and was 30 measured to be approximately 3.7.

#### 5.4 Activity measurements

Activity measurements for determination of pH and temperature optimum were made by following the formation of reducing equivalents in a 0.08% starch solution 5 (described in detail below). The reaction was stopped by adding an alkaline sodium phosphate solution (0.112 M Na<sub>2</sub>HPO<sub>4</sub>, 2 H<sub>2</sub>O; 55 mM NaOH in distilled water). Then a colour reagent (3.5 mM K<sub>3</sub>(Fe(CN)<sub>6</sub>; 56 mM Na<sub>2</sub>HPO<sub>4</sub>, 2 H<sub>2</sub>O; 55 mM 10 NaOH in distilled water) was added. The samples were boiled for 5 min. After cooling, 300 µl of the samples were transferred to a microtiter plate and absorbance at 405 nm was measured. Activity was determined from absorbance differences between samples and a blank. Glucose was used as a standard.

The enzyme solution contained an enzyme activity of 176 µmol reducing equivalents/min/ml when measured in an acetate buffer, pH 6 (acetic acid) at 50°C.

15

##### 5.4.1 pH optimum

pH optimum was determined as follows: To 400 µl 0.1% starch solution in 100 mM of either MES (pH 4.8 to 7) or MOPS (pH 7 to 8) buffers was added 75 µl of 20 enzyme solution (0.16 µmol reducing equivalents/min/ml). After 6 min. the activity was stopped by adding 240 µl stop solution. Then 360 µl colour reagent was added, and the samples were boiled for 5 min. Activity was determined as described above.

The pH optimum of the recombinant  $\alpha$ -amylase of the present invention was 25 measured to be from 5.8 to 6 (see Figure 6).

##### 5.4.2 Temperature optimum

Temperature optimum was determined as follows: 75 µl 0.5% starch solution in 100 30 mM sodium acetate buffer, pH 6 (acetic acid) was placed in a water bath thermostatted at the measuring temperature. Then 400 µl  $\alpha$ -amylase (29 nmol reducing equivalents/min/ml) was added. Enzyme activity was stopped after 5 and 8

- 27 -

min., respectively by adding 240  $\mu$ l stop solution. 360  $\mu$ l colour reagent was added and activity was determined as described above.

5 Results are shown in Figure 7. The same results were obtained when 100 mM MES buffer at pH 6 was used. The temperature optimum of the recombinant  $\alpha$ -amylase of the present invention was determined to be between 60 and 70°C.

### 5.5 Heat stability

10 Heat stability was determined as follows: 600  $\mu$ l 100 mM sodium acetate buffer, pH 6 (acetic acid) was placed in a water bath maintained at the measuring temperature. 50  $\mu$ l enzyme solution was added and after appropriate time intervals 100  $\mu$ l samples were taken out and immediately added to 750  $\mu$ l acetate buffer which was kept on ice.

15  $\alpha$ -Amylase activity in these samples was determined by incubating 400  $\mu$ l of the samples with 75  $\mu$ l 0.5% starch solution in 0.1 M acetate buffer, pH 6 at 50°C for 10 min. 240  $\mu$ l stop solution and 360  $\mu$ l colour reagent were added and activity was determined as described above.

20 Heat inactivation of the enzyme is an exponential function of time and heat stability at different temperatures can be described by the half times of inactivation. The results are presented in Table 1.

TABLE 1

temperature (°C)	half time (min)
60	89
65	29
70	16
75	6
80	3
85	2

### 5.6 Starch degrading profile

To 2.5 ml 5% starch solution in water was added 250  $\mu$ l enzyme solution (1.5  $\mu$ mol reducing equivalents/min/ml). The samples were incubated at 50°C and enzyme activity was stopped by boiling the samples after 0.5, 1, 1.5, 2, 3, 4 and 5 hours, respectively. The samples were diluted 20 times in water and analysed on a Dionex HPAEC system on a CarboPac Pa-1 column (4 x 250 mm, flow 1 ml/min) with 0.2 M NaOH, 1.5 M NaOAc and water as eluents in a gradient optimized for separation of glucose oligomers. 0.3 M NaOH was added after the separation column and the dextrins were detected by PAD (pulse amperometric detection). 20  $\mu$ l samples were applied to the column.

The results are shown in Figure 8, which show the oligomer pattern in starch samples when treated with  $\alpha$ -amylase as mentioned above. B0 is the control (i.e. no enzyme, stopped after 5 hrs), whereas the other plots are for the enzyme of the present invention wherein B1 is stoppage at 0.5 hrs, B2 is stoppage at 1 hrs, B3 is stoppage at 1.5 hrs, B4 is stoppage at 2 hrs, B5 is stoppage at 3 hrs, B6 is stoppage at 4 hrs and B7 is stoppage at 5 hrs. In Figure 8, the peak identification is that for glucose, retention time 7.1 min (in B7, glucose peaks at retention time 11.2 which can not be explained); maltose, retention time 15.9 min.; maltotriose, retention time 17 min. and maltotetraose, retention time 18 min.

The results show that the recombinant  $\alpha$ -amylase of the present invention is endo-specific, producing only a little glucose. After 5 hrs., only 4% of the total peak area is due to glucose, whereas maltose accounts for 39%.

- 29 -

6. Baking Study

In this example, the beneficial effect of the  $\alpha$ -amylase of the present invention in the manufacture of bread is illustrated.

5

Bread was prepared as follows:

	Recipe:	flour	2000 g
		dry yeast	30 g
10		sugar	30 g
		salt	30 g
		water	400 BU + 60 g

BU refers to Brabender units

15

	Procedure:	kneading	Hobart
			2 + 12 min.
			(depending on flour)
		dough temperature	24°C
20		resting	10 min. at 30°C
		scaling	2 x 375 g
		resting	5 min. at 33°C, 85% RH
		moulding	mono 11
		proofing	50 min. at 33°C, 85% RH
25		baking	40 min. at 220°C
			10 sec. steam

Enzyme addition:

1. control, no addition
2. TAKA amylase, 100 FAU/kg flour
- 30 3. Recombinant  $\alpha$ -amylase of the present invention, 100 FAU/kg flour
4. TAKA amylase, 350 FAU/kg flour
5. Recombinant  $\alpha$ -amylase of the present invention, 350 FAU/kg flour

- 30 -

Handling properties and stickiness of the dough were evaluated during preparation of the bread and after baking the crumb was evaluated.

After baking, the bread was stored in plastic bags at 20°C. Firmness of the bread 5 crumb was measured on day 3 and 7 using an Instron apparatus. 8 slices from each bread loaf were measured and the mean value was calculated. The results are shown in Figure 9.

As can be seen from Figure 9, there is a dosage effect of the recombinant  $\alpha$ -amylase 10 of the present invention. Furthermore, the enzyme of the present invention clearly has a beneficial effect on firmness.

Furthermore, the recombinant  $\alpha$ -amylase of the present invention lowers firmness as compared to a high dosage of TAKA amylase, meaning that it is a better anti-staling 15 enzyme than the TAKA amylase.

Dough handling properties were similar for doughs prepared with TAKA amylase and with the recombinant  $\alpha$ -amylase of the present invention.

20 The crumb of bread with the recombinant  $\alpha$ -amylase of the present invention was evaluated and was found to be more moist than the crumb of bread baked with TAKA amylase.

In summation the present invention relates to a recombinant  $\alpha$ -amylase and its use in 25 baking. Other aspects of the present invention include the deposited microorganisms, and mutants, variants and progeny obtained directly or indirectly therefrom and retaining the ability, when cultured, of producing a recombinant  $\alpha$ -amylase having the activity described herein.

30 Other modifications of the present invention will be apparent to those skilled in the art.

- 31 -

SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT:

- (A) NAME: DANISCO A/S
- (B) STREET: Langebrogade 1, P.O. Box 17
- (C) CITY: Copenhagen
- (E) COUNTRY: Denmark
- (F) POSTAL CODE (ZIP): 1001
- (G) TELEPHONE: +45 32 66 22 00
- (H) TELEFAX: +45 32 66 21 67

(ii) TITLE OF INVENTION: Alpha amylase from *Thermomyces lanuginosus*

(iii) NUMBER OF SEQUENCES: 11

(iv) COMPUTER READABLE FORM:

- (A) MEDIUM TYPE: Floppy disk
- (B) COMPUTER: IBM PC compatible
- (C) OPERATING SYSTEM: PC-DOS/MS-DOS
- (D) SOFTWARE: PatentIn Release #1.0, Version #1.30 (EPO)

(2) INFORMATION FOR SEQ ID NO: 1:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 3311 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: *Thermomyces lanuginosus*

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION:join(427..585, 660..698, 755..876, 956..1064, 1142..1370, 1425..1584, 1637..1783, 1846..2086, 2168..2443)

(ix) FEATURE:

- (A) NAME/KEY: sig\_peptide
- (B) LOCATION:427..480

(ix) FEATURE:

- (A) NAME/KEY: mat\_peptide
- (B) LOCATION:join(481..585, 660..698, 755..876, 956..1064, 1142..1370, 1425..1584, 1637..1783, 1846..2086, 2168..2440)

(ix) FEATURE:

- (A) NAME/KEY: exon
- (B) LOCATION:427..585

- 32 -

- (ix) FEATURE:
  - (A) NAME/KEY: intron
  - (B) LOCATION:586..659
- (ix) FEATURE:
  - (A) NAME/KEY: exon
  - (B) LOCATION:660..698
- (ix) FEATURE:
  - (A) NAME/KEY: intron
  - (B) LOCATION:699..754
- (ix) FEATURE:
  - (A) NAME/KEY: exon
  - (B) LOCATION:755..876
- (ix) FEATURE:
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  - (B) LOCATION:877..955
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  - (B) LOCATION:956..1064
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  - (B) LOCATION:1065..1141
- (ix) FEATURE:
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  - (B) LOCATION:1142..1370
- (ix) FEATURE:
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  - (B) LOCATION:1371..1424
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  - (B) LOCATION:1425..1584
- (ix) FEATURE:
  - (A) NAME/KEY: intron
  - (B) LOCATION:1585..1636
- (ix) FEATURE:
  - (A) NAME/KEY: exon
  - (B) LOCATION:1637..1783
- (ix) FEATURE:
  - (A) NAME/KEY: intron
  - (B) LOCATION:1784..1845
- (ix) FEATURE:
  - (A) NAME/KEY: exon
  - (B) LOCATION:1846..2086
- (ix) FEATURE:

- 33 -

(A) NAME/KEY: intron  
 (B) LOCATION: 2087..2167

(ix) FEATURE:

(A) NAME/KEY: exon  
 (B) LOCATION: 2168..2443

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 1:

GTTCATTGG GCGTGATGAG ATGCCGTCGC GGGTGGAGTT GTCTGCCAT CACAATAAAC	60
CTTGTCCAA ACATTTGCCT AATTGCCAT CACCAACGGC TTTAAGAACATC ATGTACCTCG	120
CTCATTGAG AAGATGGAAG ATGCCATTGC CACGGCAGTC GATCAATCTA CTGGCTATGG	180
ATGGTCCGAA TTTCCGTCG TCGCCTTTG CTCTAATCTC GGTATGACCT TCACCGAGCG	240
AATCGTAGAA TATTTAAAGG GTTGATCGAG CCACCTTGTC GCGATGTCT GACTCTGTCG	300
TGTCACAACT GAACTGATCA GACGAGGTCA TCTGAGTCTC TCGTCGAAAA AAGACTCGTT	360
GGATGATTCT CGATTTAAC CCGGGACAAG TCATAGAACG AGTAGTACTT CAGTTGGCCA	420
CAAAG ATG AAG TCT CTC GCC GCA ATT GCT GCT CTG CTG TCG CCC ACA	468
Met Lys Ser Leu Ala Ala Ile Ala Leu Leu Ser Pro Thr	
-18 -15 -10 -5	
CTG GTC CGG GCA GCG ACT CCG GAT GAG TGG AAA GCT CAG TCG ATC TAT	516
Leu Val Arg Ala Ala Thr Pro Asp Glu Trp Lys Ala Gln Ser Ile Tyr	
1 5 10	
TTC ATG CTG ACG GAC CGG TTT GCG CGT ACC GAC AAT TCG ACC ACG GCT	564
Phe Met Leu Thr Asp Arg Phe Ala Arg Thr Asp Asn Ser Thr Thr Ala	
15 20 25	
CCC TGT GAC ACC ACT GCC GGG GTATGCAACT AACCCCTGTGT TTCTCTTCCC	615
Pro Cys Asp Thr Thr Ala Gly	
30 35	
GGGACGTACA AGGGGTCTTC TCCATGCTAA CCGTGCACAT GCAG AAA TAT TGC GGG	671
Lys Tyr Cys Gly	
GGA ACA TGG CGA GGT ATC ATC AAC AAC GTAAGTGGCT TCTGATTTTC	718
Gly Thr Trp Arg Gly Ile Ile Asn Asn	
40 45	
GCTCAATAAT CTTCGTCGCG TGACTTTATT TCCTAG CTG GAT TAC ATC CAG GAT	772
Leu Asp Tyr Ile Gln Asp	
50	
ATG GGC TTC ACA GCT ATC TGG ATA ACT CCA GTG ACA GCC CAG TGG GAC	820
Met Gly Phe Thr Ala Ile Trp Ile Thr Pro Val Thr Ala Gln Trp Asp	
55 60 65 70	
GAC GAT GTG GAT GCG GCA GAT GCA ACG TCG TAT CAC GGT TAT TGG CAG	868

- 34 -

Asp Asp Val Asp Ala Ala Asp Ala Thr Ser Tyr His Gly Tyr Trp Gln			
75	80	85	
AAA GAC CT GTGCGCAACC CTGCTCCATG GATCGCTGGC TGCAAACTCG		916	
Lys Asp Leu			
TGCTGATCGG TGATTTTTT TTTTTTTTT TTGAAACAG A TAC TCT CTG AAT TCG		971	
Tyr Ser Leu Asn Ser			
90			
AAA TTC GGC ACT GCC GAT GAC TTG AAA GCC CTG GCT GAT GCC CTT CAC		1019	
Lys Phe Gly Thr Ala Asp Asp Leu Lys Ala Leu Ala Asp Ala Leu His			
95	100	105	110
GCC CGT GGG ATG CTT CTC ATG GTC GAC GTC GTG GCT AAT CAC TTT		1064	
Ala Arg Gly Met Leu Leu Met Val Asp Val Val Ala Asn His Phe			
115	120	125	
GTACGGACCA TCTACATACC TGGGAAACGC GAAGAAGGAA AAAAAAAA AGGCGCACGC		1124	
TAACATTCG CGTTTAG GGC TAC GGC GGT TCT CAT AGC GAG GTG GAT TAC		1174	
Gly Tyr Gly Ser His Ser Glu Val Asp Tyr			
130	135		
TCG ATC TTC AAT CCT CTG AAC AGC CAG GAT TAC TTC CAC CCG TTC TGT		1222	
Ser Ile Phe Asn Pro Leu Asn Ser Gln Asp Tyr Phe His Pro Phe Cys			
140	145	150	
CTC ATT GAG GAC TAC GAC AAC CAG GAA GAA GTC GAA CAA TGC TGG CTG		1270	
Leu Ile Glu Asp Tyr Asp Asn Gln Glu Glu Val Glu Gln Cys Trp Leu			
155	160	165	
GCC GAT ACT CCG ACG ACA TTG CCC GAC GTG GAC ACC ACC AAT CCT CAG		1318	
Ala Asp Thr Pro Thr Thr Leu Pro Asp Val Asp Thr Thr Asn Pro Gln			
170	175	180	
GTT CGG ACG TTT TTC AAC GAC TGG ATC AAG AGC CTG GTG GCG AAC TAC		1366	
Val Arg Thr Phe Asn Asp Trp Ile Lys Ser Leu Val Ala Asn Tyr			
185	190	195	200
TCC A GTATGATTGT TCCCGCGGTA ACGCTTAGG GCTTGCTCTA ACTGAAATCG		1420	
Ser			
ACAG TC GAT GGT CTG CGC GTC GAC ACC GTT AAG CAC GTG GAG AAA GAT		1468	
Ile Asp Gly Leu Arg Val Asp Thr Val Lys His Val Glu Lys Asp			
205	210	215	
TTC TGG CCC GAC TTC AAC GAA GCT GCT GCG TGT ACC GTC GGC GAG GTG		1516	
Phe Trp Pro Asp Phe Asn Glu Ala Ala Ala Cys Thr Val Gly Glu Val			
220	225	230	
TTC AAC GGT GAC CCA GCG TAC ACC TGC CCA TAC CAG GAA GTG CTG GAT		1564	
Phe Asn Gly Asp Pro Ala Tyr Thr Cys Pro Tyr Gln Glu Val Leu Asp			
235	240	245	

- 35 -

GGC GTT CTG AAC TAT CCG AT	GTGAGTGATT CCGAAAGTTC CATCGATCAG			1614
Gly Val Leu Asn Tyr Pro Ile				
250	255			
GCTTTCTGAC GCATGAGAAC AG C TAC TAT CCT GCG CTT GAT GCA TTC AAG				1664
Tyr Tyr Pro Ala Leu Asp Ala Phe Lys				
260				
TCT GTC GGC GGC AAT CTC GGC GGC TTG GCT CAG GCC ATC ACC ACC GTG				1712
Ser Val Gly Gly Asn Leu Gly Leu Ala Gln Ala Ile Thr Thr Val				
265	270	275	280	
CAG GAG AGC TGC AAG GAT TCC AAT CTG CTC GGC AAT TTC CTT GAG AAT				1760
Gln Glu Ser Cys Lys Asp Ser Asn Leu Leu Gly Asn Phe Leu Glu Asn				
285	290	295		
CAC GAC ATT GCT CGC TTT GCT TC	GTATGGACAC TCTTTTGAA			1803
His Asp Ile Ala Arg Phe Ala Ser				
300				
GCCCTCATCG ATTGGGGATG CTGACACGGA CAACAAACAC AG G TAC ACG GAT GAC				1858
Tyr Thr Asp Asp				
305				
CTT GCT CTC GCC AAG AAT GGT CTC GCT TTC ATC ATC CTC TCG GAT GGT				1906
Leu Ala Leu Ala Lys Asn Gly Leu Ala Phe Ile Ile Leu Ser Asp Gly				
310	315	320		
ATT CCG ATC ATC TAC ACG GGC CAG GAG CAG CAC TAC GCC GGT GAT CAC				1954
Ile Pro Ile Ile Tyr Thr Gly Gln Glu Gln His Tyr Ala Gly Asp His				
325	330	335	340	
GAT CCC ACA AAT CGT GAG GCC GTC TGG CTG TCT GGC TAC AAT ACC GAC				2002
Asp Pro Thr Asn Arg Glu Ala Val Trp Leu Ser Gly Tyr Asn Thr Asp				
345	350	355		
GCC GAG CTG TAC CAG TTC ATC AAG AAG GCC AAT GGC ATC CGC AAC TTG				2050
Ala Glu Leu Tyr Gln Phe Ile Lys Lys Ala Asn Gly Ile Arg Asn Leu				
360	365	370		
GCT ATC AGC CAG AAC CCG GAA TTC ACC TCC TCC AAG GTGAGTACAA				2096
Ala Ile Ser Gln Asn Pro Glu Phe Thr Ser Ser Lys				
375	380			
TAACAAACTT TTGAAAAAT TTTCACCGG AGAAAACCTA AGATTCGGCT AACAAAACAA				2156
AAAAAAAAAA G ACC AAG GTC ATC TAC CAA GAC GAT TCG ACC CTT GCC ATT				2206
Thr Lys Val Ile Tyr Gln Asp Asp Ser Thr Leu Ala Ile				
385	390	395		
AAC CGG GGC GGC GTC GTT ACT GTC CTG AGC AAT GAA GGC GCC TCC GGG				2254
Asn Arg Gly Val Val Thr Val Leu Ser Asn Glu Gly Ala Ser Gly				
400	405	410		
GAG ACC GGG ACT GTC TCC ATT CCG GGA ACT GGC TTC GAG GCC GGC ACG				2302
Glu Thr Gly Thr Val Ser Ile Pro Gly Thr Gly Phe Glu Ala Gly Thr				
415	420	425		

- 36 -

GAA TTG ACT GAT GTC ATC TCC TGC AAG ACC GTG ACT GCG GGG GAC AGC Glu Leu Thr Asp Val Ile Ser Cys Lys Thr Val Thr Ala Gly Asp Ser 430 435 440 445	2350
GGG GCG GTC GAC GTG CCC TTG TCG GGC GGA CTG CCA AGC GTG CTC TAT Gly Ala Val Asp Val Pro Leu Ser Gly Gly Leu Pro Ser Val Leu Tyr 450 455 460	2398
CCC AGC TCC CAG CTG GCC AAG AGT GGT CTG TGT GCG TCG GCG TGA Pro Ser Ser Gln Leu Ala Lys Ser Gly Leu Cys Ala Ser Ala *465 470 475	2443
GGGGATTCTC TCATCACCAAG GCGATGTCAG GAGACAATT TTTCTGAAC TCAGGGGTTT CTCAGAGAGC TCAAAATCGG GAACTTTTT TTTGCAGGAA CTCCGAGTGT ACATATATTG AGTGGAGTCT CTCATTCGTC TTTTGTGTAG CTTAGGTTGA TCCATAGTGA GTGATTTTC ACGTTGCTCC ACGTGGTTT CTTGACAGTT CGGGCTATGG GGTGTTAGCC TTGTTGGGCA CGAAGATCCA CACTAAAATC TGACACTATG AAGTCAACTC ACCATCCTGA TCGGATTTGT GCTCTCATTC CGTCATTTGT CCAATCAACT CTCCGTAAC CCCCCATCCTA ACTCCCTCCC CAAGTGAACC TATTCCTTT CTTGTTTCGT AAGCTCCCCA AGGTCCAATG GCCATGTCAC TTTGATGACG CGTAGCACGT CAGCTGTTCC GTACCTTTTC TCGCCCGATC AGCGGCAGCG GCGGCGGCAGC CGCGGCAGC AGCAGCAGCA GCAGCAGCAG CAGCAGCAGC AGTCAAGGGG ACCAAACCAG GAACCCAATT CGGCAGGGAG ACGCGCCGAA TCCGCCGACG TTGAACGCGG CTAGGAGATT CTTCGCACTT TGTCCCTTTC CCATTGCTCC TCGTCATTGT AGCTTATTCC TAGTCTCGTT AAACCCGGAA CTAGCGGCCG AATGATTTGG CCACCGCTTC CATACTATGG TACACCTGCG CTGTACTCCG GACGCAGAAT GTCGGCCTTT ACGCCCCAAT CCCTGTACCT CGGAGTTATG GTTCGAAGAG TGAATCCTCT TCGATTGCAC ACTTCATGAC ACAGAAGCCG CTTCGTAATC CCAATCCAAT TGCTGCAG	2503 2563 2623 2683 2743 2803 2863 2923 2983 3043 3103 3163 3223 3283 3311

(2) INFORMATION FOR SEQ ID NO: 2:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 494 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 2:

Met Lys Ser Leu Ala Ala Ile Ala Ala Leu Leu Ser Pro Thr Leu Val			
-18	-15	-10	-5

- 37 -

Arg Ala Ala Thr Pro Asp Glu Trp Lys Ala Gln Ser Ile Tyr Phe Met  
 1 5 10  
 Leu Thr Asp Arg Phe Ala Arg Thr Asp Asn Ser Thr Thr Ala Pro Cys  
 15 20 25 30  
 Asp Thr Thr Ala Gly Lys Tyr Cys Gly Gly Thr Trp Arg Gly Ile Ile  
 35 40 45  
 Asn Asn Leu Asp Tyr Ile Gln Asp Met Gly Phe Thr Ala Ile Trp Ile  
 50 55 60  
 Thr Pro Val Thr Ala Gln Trp Asp Asp Asp Val Asp Ala Ala Asp Ala  
 65 70 75  
 Thr Ser Tyr His Gly Tyr Trp Gln Lys Asp Leu Tyr Ser Leu Asn Ser  
 80 85 90  
 Lys Phe Gly Thr Ala Asp Asp Leu Lys Ala Leu Ala Asp Ala Leu His  
 95 100 105 110  
 Ala Arg Gly Met Leu Leu Met Val Asp Val Val Ala Asn His Phe Gly  
 115 120 125  
 Tyr Gly Gly Ser His Ser Glu Val Asp Tyr Ser Ile Phe Asn Pro Leu  
 130 135 140  
 Asn Ser Gln Asp Tyr Phe His Pro Phe Cys Leu Ile Glu Asp Tyr Asp  
 145 150 155  
 Asn Gln Glu Glu Val Glu Gln Cys Trp Leu Ala Asp Thr Pro Thr Thr  
 160 165 170  
 Leu Pro Asp Val Asp Thr Thr Asn Pro Gln Val Arg Thr Phe Phe Asn  
 175 180 185 190  
 Asp Trp Ile Lys Ser Leu Val Ala Asn Tyr Ser Ile Asp Gly Leu Arg  
 195 200 205  
 Val Asp Thr Val Lys His Val Glu Lys Asp Phe Trp Pro Asp Phe Asn  
 210 215 220  
 Glu Ala Ala Ala Cys Thr Val Gly Glu Val Phe Asn Gly Asp Pro Ala  
 225 230 235  
 Tyr Thr Cys Pro Tyr Gln Glu Val Leu Asp Gly Val Leu Asn Tyr Pro  
 240 245 250  
 Ile Tyr Tyr Pro Ala Leu Asp Ala Phe Lys Ser Val Gly Gly Asn Leu  
 255 260 265 270  
 Gly Gly Leu Ala Gln Ala Ile Thr Thr Val Gln Glu Ser Cys Lys Asp  
 275 280 285  
 Ser Asn Leu Leu Gly Asn Phe Leu Glu Asn His Asp Ile Ala Arg Phe  
 290 295 300

- 38 -

Ala Ser Tyr Thr Asp Asp Leu Ala Leu Ala Lys Asn Gly Leu Ala Phe  
 305 310 315  
 Ile Ile Leu Ser Asp Gly Ile Pro Ile Ile Tyr Thr Gly Gln Glu Gln  
 320 325 330  
 His Tyr Ala Gly Asp His Asp Pro Thr Asn Arg Glu Ala Val Trp Leu  
 335 340 345 350  
 Ser Gly Tyr Asn Thr Asp Ala Glu Leu Tyr Gln Phe Ile Lys Lys Ala  
 355 360 365  
 Asn Gly Ile Arg Asn Leu Ala Ile Ser Gln Asn Pro Glu Phe Thr Ser  
 370 375 380  
 Ser Lys Thr Lys Val Ile Tyr Gln Asp Asp Ser Thr Leu Ala Ile Asn  
 385 390 395  
 Arg Gly Gly Val Val Thr Val Leu Ser Asn Glu Gly Ala Ser Gly Glu  
 400 405 410  
 Thr Gly Thr Val Ser Ile Pro Gly Thr Gly Phe Glu Ala Gly Thr Glu  
 415 420 425 430  
 Leu Thr Asp Val Ile Ser Cys Lys Thr Val Thr Ala Gly Asp Ser Gly  
 435 440 445  
 Ala Val Asp Val Pro Leu Ser Gly Gly Leu Pro Ser Val Leu Tyr Pro  
 450 455 460  
 Ser Ser Gln Leu Ala Lys Ser Gly Leu Cys Ala Ser Ala \*  
 465 470 475

(2) INFORMATION FOR SEQ ID NO: 3:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 19 base pairs
  - (B) TYPE: nucleic acid
  - (C) STRANDEDNESS: single
  - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
  - (A) DESCRIPTION: /desc = "adaptor upper strand"
- (iv) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 3:

GATCGTTAA ACGGCGCCG

19

(2) INFORMATION FOR SEQ ID NO: 4:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 19 base pairs
  - (B) TYPE: nucleic acid

- 39 -

- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid  
(A) DESCRIPTION: /desc = "adaptor lower strand"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 4:

AATTGGCGC CGTTAAC

19

(2) INFORMATION FOR SEQ ID NO: 5:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 23 base pairs
  - (B) TYPE: nucleic acid
  - (C) STRANDEDNESS: single
  - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 5:

ATGGGNTTYA CNGCNATHG GAT

23

(2) INFORMATION FOR SEQ ID NO: 6:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 20 base pairs
  - (B) TYPE: nucleic acid
  - (C) STRANDEDNESS: single
  - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 6:

TTYTGRANG GRCANGTRTA

20

(2) INFORMATION FOR SEQ ID NO: 7:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 245 base pairs
  - (B) TYPE: nucleic acid
  - (C) STRANDEDNESS: double
  - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA

(iv) ANTI-SENSE: NO

- 40 -

(vi) ORIGINAL SOURCE:  
 (A) ORGANISM: Thermomyces lanuginosus  
 (B) STRAIN: CBS 223.63

(ix) FEATURE:  
 (A) NAME/KEY: CDS  
 (B) LOCATION: join(2..105, 185..245)

(ix) FEATURE:  
 (A) NAME/KEY: intron  
 (B) LOCATION: 106..184

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 7:

T ATG GGG TTT ACG GCG ATA TGG ATT ACT CCA GTG ACA GCC CAG TGG	46
Met Gly Phe Thr Ala Ile Trp Ile Thr Pro Val Thr Ala Gln Trp	
1 5 10 15	
GAC GAC GAT GTG GAT GCG GCA GAT GCA ACG TCG TAT CAC GGT TAT TGG	94
Asp Asp Asp Val Asp Ala Ala Asp Ala Thr Ser Tyr His Gly Tyr Trp	
20 25 30	
CAG AAA GAC CT GTGCGCAACC CTGCTCCATG GATCGCTGGC TGCAAACCTCG	145
Gln Lys Asp Leu	
35	
TGCTGATCGG TGATTTTTT TTTTTTTTT TTGAAACAG A TAC TCT CTG AAT TCG	200
Tyr Ser Leu Asn Ser	
40	
AAA TTC GGC ACT GCC GAT GAC TTG AAA ACC CTG GCT GAT GCC CTT	245
Lys Phe Gly Thr Ala Asp Asp Leu Lys Thr Leu Ala Asp Ala Leu	
45 50 55	

(2) INFORMATION FOR SEQ ID NO: 8:

(i) SEQUENCE CHARACTERISTICS:  
 (A) LENGTH: 55 amino acids  
 (B) TYPE: amino acid  
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein  
 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 8:

Met Gly Phe Thr Ala Ile Trp Ile Thr Pro Val Thr Ala Gln Trp Asp	
1 5 10 15	
Asp Asp Val Asp Ala Ala Asp Ala Thr Ser Tyr His Gly Tyr Trp Gln	
20 25 30	
Lys Asp Leu Tyr Ser Leu Asn Ser Lys Phe Gly Thr Ala Asp Asp Leu	
35 40 45	
Lys Thr Leu Ala Asp Ala Leu	
50 55	

- 41 -

(2) INFORMATION FOR SEQ ID NO: 9:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 256 base pairs
  - (B) TYPE: nucleic acid
  - (C) STRANDEDNESS: single
  - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA
- (ix) FEATURE:
  - (A) NAME/KEY: CDS
  - (B) LOCATION:join(1..73, 128..256)
- (x) FEATURE:
  - (A) NAME/KEY: intron
  - (B) LOCATION:74..255

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 9:

GTG GAC ACC ACC AAT CCT CAG GTT CGG ACG TTT TTC AAC GAC TGG ATC	48
Val Asp Thr Thr Asn Pro Gln Val Arg Thr Phe Phe Asn Asp Trp Ile	
1 5 10 15	
AAG AGC CTG GTG GTT AAC TAC TCC A GTATGATTGT TCCCGCGGTA	93
Lys Ser Leu Val Val Asn Tyr Ser	
20	
ACGCTTTAGG GCTTGCTCTA ACTGAAATCG ACAG TC GAT GGT CTG CGC GTC	144
Ile Asp Gly Leu Arg Val	
25 30	
GAC ACC GTT AAG CAC GTG GAG AAA GAT TTC TGG CCC GAC TTC AAC GAA	192
Asp Thr Val Lys His Val Glu Lys Asp Phe Trp Pro Asp Phe Asn Glu	
35 40 45	
GCT GCT GCG TGT ACC GTC GGC GAG GTG TTC AAC GGT GAC CCA GCG TAC	240
Ala Ala Ala Cys Thr Val Glu Val Phe Asn Gly Asp Pro Ala Tyr	
50 55 60	
ACA TGC CCC TAC CAG A	256
Thr Cys Pro Tyr Gln	
65	

(2) INFORMATION FOR SEQ ID NO: 10:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 67 amino acids
  - (B) TYPE: amino acid
  - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: protein
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 10:

- 42 -

Val Asp Thr Thr Asn Pro Gln Val Arg Thr Phe Phe Asn Asp Trp Ile  
1 5 10 15

Lys Ser Leu Val Val Asn Tyr Ser Ile Asp Gly Leu Arg Val Asp Thr  
20 25 30

Val Lys His Val Glu Lys Asp Phe Trp Pro Asp Phe Asn Glu Ala Ala  
35 40 45

Ala Cys Thr Val Gly Glu Val Phe Asn Gly Asp Pro Ala Tyr Thr Cys  
50 55 60

Pro Tyr Gln  
65

(2) INFORMATION FOR SEQ ID NO: 11:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 10 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: peptide

(v) FRAGMENT TYPE: N-terminal

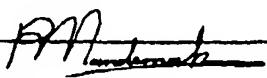
(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 11:

Ala Thr Pro Asp Glu Trp Lys Ala Gln Ser  
1 5 10

43

## INDICATIONS RELATING TO A DEPOSITED MICROORGANISM

(PCT Rule 15b(w))

<p>A. The indications made below relate to the microorganism referred to in the description on page <u>17</u> line <u>5</u> 19-26</p>	
<p>B. IDENTIFICATION OF DEPOSIT</p> <p>Further deposits are identified on an additional sheet <input type="checkbox"/></p> <p>Name of depositary institution The National Collections of Industrial and Marine Bacteria Limited (NCIMB)</p> <p>Address of depositary institution (including postal code and country) 23 St Machar Drive Aberdeen Scotland AB2 1RY United Kingdom</p>	
Date of deposit 23 June 1994	Accession Number NCIMB 40655
<p>C. ADDITIONAL INDICATIONS (leave blank if not applicable) This information is continued on an additional sheet <input type="checkbox"/></p> <p>In respect of those designations in which a European patent is sought, and any other designated state having equivalent legislation, a sample of the deposited microorganism will be made available until the publication of the mention of the grant of the patent or until the date on which the application has been refused or withdrawn or is deemed to be withdrawn, only by the issue of such a sample to an expert nominated by the person requesting the sample (cf Rule 28(4) EPC).</p>	
<p>D. DESIGNATED STATES FOR WHICH INDICATIONS ARE MADE (if the indications are not for all designated States)</p>	
<p>E. SEPARATE FURNISHING OF INDICATIONS (leave blank if not applicable)</p> <p>The indications listed below will be submitted to the International Bureau later (specify the general nature of the indications e.g., 'Accession Number of Deposit')</p>	
<p>For receiving Office use only</p> <p><input checked="" type="checkbox"/> This sheet was received with the international application</p> <p>Authorized officer  R. Mandemak</p>	
<p>For International Bureau use only</p> <p><input type="checkbox"/> This sheet was received by the International Bureau on:</p> <p>Authorized officer</p>	

## INDICATIONS RELATING TO A DEPOSITED MICROORGANISM

(PCT Rule 15(b))

A. The indications made below relate to the microorganism referred to in the description on page 17 line s 19-26

## B. IDENTIFICATION OF DEPOSIT

Further deposits are identified on an additional sheet 

Name of depository institution

The National Collections of Industrial and Marine Bacteria Limited (NCIMB)

Address of depository institution (including postal code and country)

23 St Machar Drive  
Aberdeen  
Scotland  
AB2 1RY  
United Kingdom

Date of deposit:

23 June 1994

Accession Number

NCIMB 40656

C. ADDITIONAL INDICATIONS (leave blank if not applicable) This information is continued on an additional sheet 

In respect of those designations in which a European patent is sought, and any other designated state having equivalent legislation, a sample of the deposited microorganism will be made available until the publication of the mention of the grant of the patent or until the date on which the application has been refused or withdrawn or is deemed to be withdrawn, only by the issue of such a sample to an expert nominated by the person requesting the sample (cf Rule 28(4) EPC).

D. DESIGNATED STATES FOR WHICH INDICATIONS ARE MADE (if the indications are not for all designated States)

E. SEPARATE FURNISHING OF INDICATIONS (leave blank if not applicable)

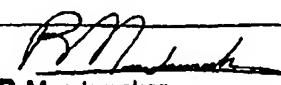
The indications listed below will be submitted to the International Bureau later (specify the general nature of the indications e.g., 'Accession Number of Deposit')

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## INDICATIONS RELATING TO A DEPOSITED MICROORGANISM

(PCT Rule 13bis)

A. The indications made below relate to the microorganism referred to in the description on page <u>17</u> , lines <u>19-26</u>	
B. IDENTIFICATION OF DEPOSIT <span style="float: right;"><input type="checkbox"/> Further deposits are identified on an additional sheet</span>	
Name of depository institution  The National Collections of Industrial and Marine Bacteria Limited (NCIMB)	
Address of depository institution (including postal code and country) 23 St Machar Drive Aberdeen Scotland AB2 1RY United Kingdom	
Date of deposit 23 June 1994	Accession Number NCIMB 40657
C. ADDITIONAL INDICATIONS (leave blank if not applicable) <span style="float: right;"><input type="checkbox"/> This information is continued on an additional sheet</span>	
In respect of those designations in which a European patent is sought, and any other designated state having equivalent legislation, a sample of the deposited microorganism will be made available until the publication of the mention of the grant of the patent or until the date on which the application has been refused or withdrawn or is deemed to be withdrawn, only by the issue of such a sample to an expert nominated by the person requesting the sample (cf Rule 28(4) EPC).	
D. DESIGNATED STATES FOR WHICH INDICATIONS ARE MADE (if the indications are not for all designated States)	
E. SEPARATE FURNISHING OF INDICATIONS (leave blank if not applicable)	
The indications listed below will be submitted to the International Bureau later (specify the general nature of the indications e.g., 'Accession Number of Deposit')	
For receiving Office use only <input checked="" type="checkbox"/> This sheet was received with the international application	
For International Bureau use only <input type="checkbox"/> This sheet was received by the International Bureau on:	
Authorized officer <u>R. Mandemaker</u> R. Mandemaker	

## INDICATIONS RELATING TO A DEPOSITED MICROORGANISM

(PCT Rule 13bis)

A. The indications made below relate to the microorganism referred to in the description  
 on page 17 line S 19-26

## B. IDENTIFICATION OF DEPOSIT

Further deposits are identified on an additional sheet 

Name of depositary institution

The National Collections of Industrial and Marine Bacteria Limited (NCIMB)

Address of depositary institution (including postal code and country)

23 St Machar Drive  
 Aberdeen  
 Scotland  
 AB2 1RY  
 United Kingdom

Date of deposit

23 June 1994

Accession Number

NCIMB 40658

C. ADDITIONAL INDICATIONS (leave blank if not applicable) This information is continued on an additional sheet 

In respect of those designations in which a European patent is sought, and any other designated state having equivalent legislation, a sample of the deposited microorganism will be made available until the publication of the mention of the grant of the patent or until the date on which the application has been refused or withdrawn or is deemed to be withdrawn, only by the issue of such a sample to an expert nominated by the person requesting the sample (cf Rule 28(4) EPC).

D. DESIGNATED STATES FOR WHICH INDICATIONS ARE MADE (if the indications are not for all designated States)

E. SEPARATE FURNISHING OF INDICATIONS (leave blank if not applicable)

The indications listed below will be submitted to the International Bureau later (specify the general nature of the indications e.g., 'Accession Number of Deposit')

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R. Mandemaker

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CLAIMS:

1. A recombinant enzyme having the following characteristics:

5           i.     $\alpha$ -amylase activity over the range from about 60°C to about 80°C;

10           ii.    a molecular weight of about 54 - 60 kDa when measured by SDS-PAGE, or of about 55265 Da +/- 100 Da when measured by mass spectrometry;

15           iii.    a pI value of about 3.7 (on a Pharmacia IEF gel, 3-9);

iv.    a pH optimum of from about 5.8 to about 6;

15           v.    a temperature optimum of from about 60°C to about 70°C.

2. A recombinant enzyme according to claim 1 wherein the enzyme comprises an N-terminal sequence shown as SEQ. I.D. No. 11.

20 3. A recombinant enzyme according to claim 1 or claim 2 wherein the enzyme comprises the sequence shown as SEQ. I.D. No. 1 or SEQ. I.D. No. 2, or a variant, homologue or fragment thereof.

25 4. A recombinant enzyme according to any one of the preceding claims wherein the enzyme is expressed by a nucleotide sequence comprising the coding sequence shown in SEQ. I.D. No. 1, or a variant, homologue or fragment thereof.

30 5. A recombinant enzyme according to any one of the preceding claims wherein the enzyme is expressed by a nucleotide sequence comprising the nucleotide sequence shown as SEQ. I.D. No. 1, or a variant, homologue or fragment thereof.

- 48 -

6. A recombinant enzyme according to any one of the preceding claims wherein the enzyme is obtained or obtainable from *T. lanuginosus*.
7. A recombinant enzyme according to any one of the preceding claims wherein 5 the enzyme is expressed by a member of the *Aspergillus* family.
8. A recombinant enzyme according to claim 7 wherein the enzyme is expressed by *Aspergillus niger*.
- 10 9. A recombinant enzyme according to any one of the preceding claims wherein the enzyme is obtainable from any one of NCIMB deposit No. 40655, NCIMB deposit No. 40656, NCIMB deposit No. 40657 and NCIMB deposit No. 40658.
- 15 10. A recombinant nucleotide sequence comprising the coding nucleotide sequence shown in SEQ. I.D. No. 1, or a variant, homologue or fragment thereof.
11. A recombinant nucleotide sequence comprising the nucleotide sequence shown as SEQ. I.D. No. 1, or a variant, homologue or fragment thereof.
- 20 12. A construct comprising the recombinant nucleotide sequence according to claim 10 or claim 11.
13. A vector comprising the recombinant nucleotide sequence according to claim 10 or claim 11 or the construct according to claim 12.
- 25 14. A cell, tissue or organism comprising the recombinant nucleotide sequence according to claim 10 or claim 11 or the construct according to claim 11 or the vector according to claim 13.
- 30 15. A transgenic organism comprising the recombinant nucleotide sequence according to claim 10 or claim 11 or the construct according to claim 12 or the vector according to claim 13 or the cell, tissue or organism according to claim 14.

16. A transgenic organism according to claim 15 wherein the organism is a filamentous fungus, preferably an *Aspergillus* fungus, preferably *Aspergillus niger*.
17. NCIMB deposit No. 40655, NCIMB deposit No. 40656, NCIMB deposit No. 5 40657 or NCIMB deposit No. 40658.
18. A method of preparing a foodstuff comprising forming a mixture by contacting starch or a starch based ingredient with an  $\alpha$ -amylase and optionally processing the mixture, wherein the  $\alpha$ -amylase is a recombinant  $\alpha$ -amylase according to any one of 10 claims 1 to 9, or is a recombinant  $\alpha$ -amylase expressed by the invention according to any one of claims 10 to 17.
19. A method according to claim 18 wherein the recombinant  $\alpha$ -amylase is incorporated into the mixture in an amount sufficient to provide from 50 to 400 units 15 of  $\alpha$ -amylase activity per kg of starch or starch based ingredient to form the mixture.
20. A method of preparing a bakery product comprising forming a mixture by contacting a wheat-flour dough with an  $\alpha$ -amylase and baking the mixture, wherein the  $\alpha$ -amylase is a recombinant  $\alpha$ -amylase according to any one of claims 1 to 9, or 20 is a recombinant  $\alpha$ -amylase expressed by the invention according to any one of claims 10 to 17.
21. A method according to claim 20 wherein the recombinant  $\alpha$ -amylase is incorporated into the dough in an amount sufficient to provide from 50 to 400 units 25 of  $\alpha$ -amylase activity per kg of wheat flour used to form the dough.
22. A method according to any one of claims 18 to 21 wherein the foodstuff or bakery product is bread.
- 30 23. A foodstuff obtained by use of the recombinant  $\alpha$ -amylase according to any one of claims 1 to 9, or a recombinant  $\alpha$ -amylase expressed by the invention according to any one of claims 10 to 17.

- 50 -

24. A bakery product obtained by use of the recombinant  $\alpha$ -amylase according to any one of claims 1 to 9, or a recombinant  $\alpha$ -amylase expressed by the invention according to any one of claims 10 to 17.

5 25. Use of a recombinant  $\alpha$ -amylase having  $\alpha$ -amylase activity over the range from about 60°C to about 80°C in preparing a foodstuff.

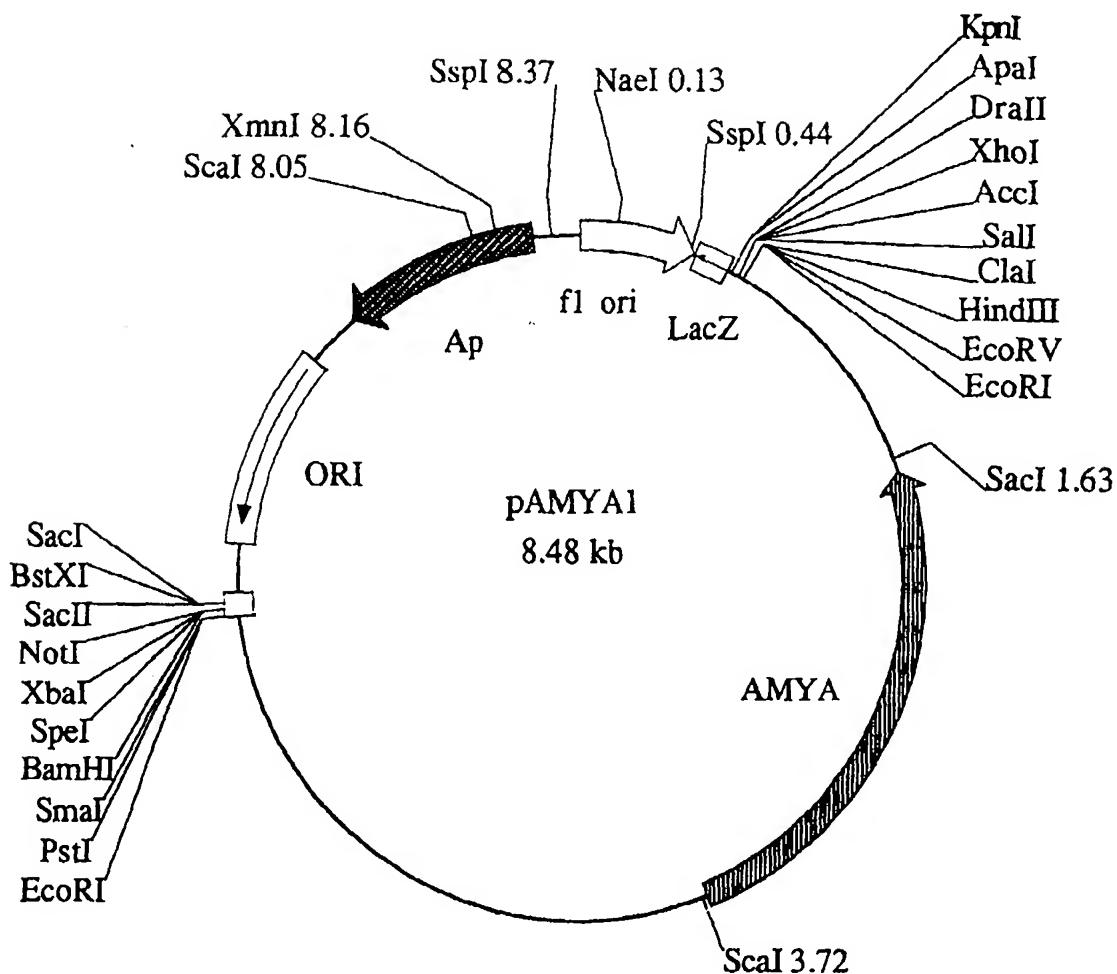
26. Use of a recombinant  $\alpha$ -amylase having  $\alpha$ -amylase activity over the range from about 60°C to about 80°C in baking.

10

27. Use according to claim 25 or claim 26 wherein the recombinant  $\alpha$ -amylase is a recombinant  $\alpha$ -amylase according to any one of claims 1 to 9, or is a recombinant  $\alpha$ -amylase expressed by the invention according to any one of claims 10 to 17.

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1 / 9



Plasmid name: pAMYA1

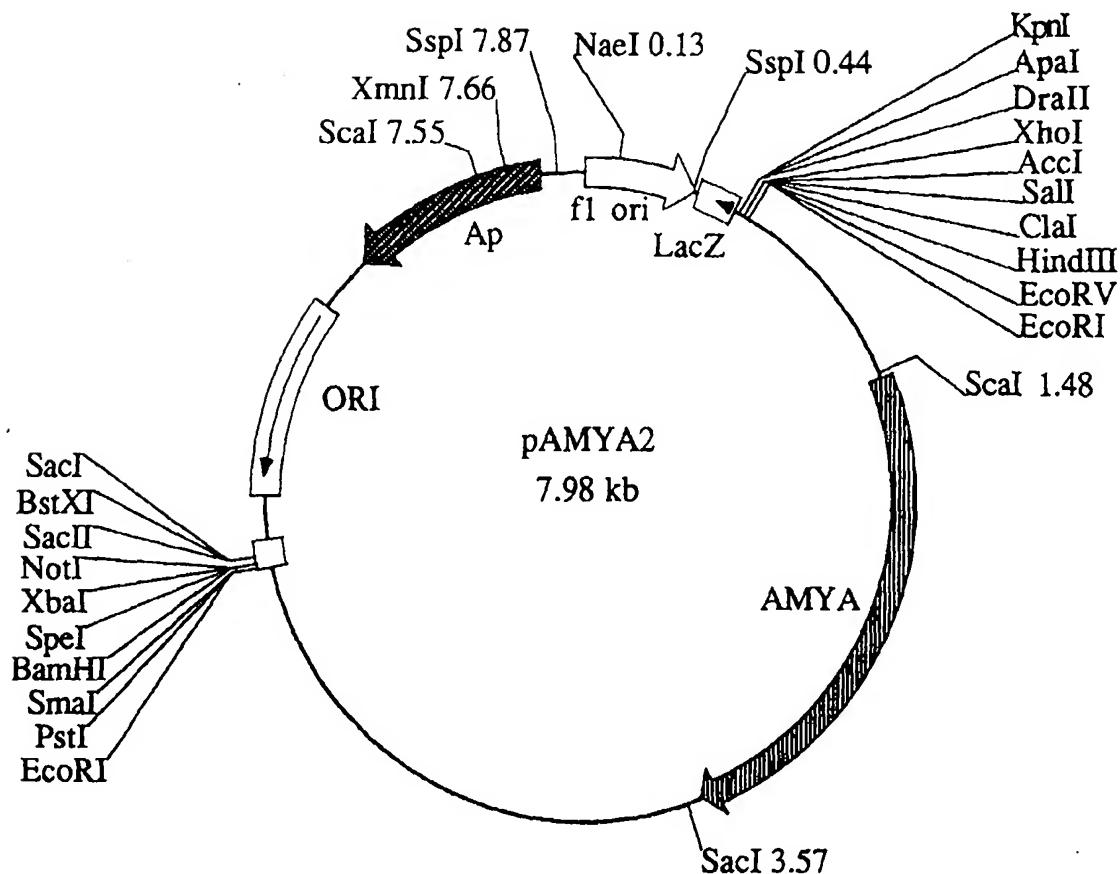
Plasmid size: 8.48 kb

Constructed by: PR, JR

Construction date: 15/3 1993

Comments: Made by *in vivo* excision of an ZAPII phage

Fig 1



Plasmid name: pAMYA2

Plasmid size: 7.98 kb

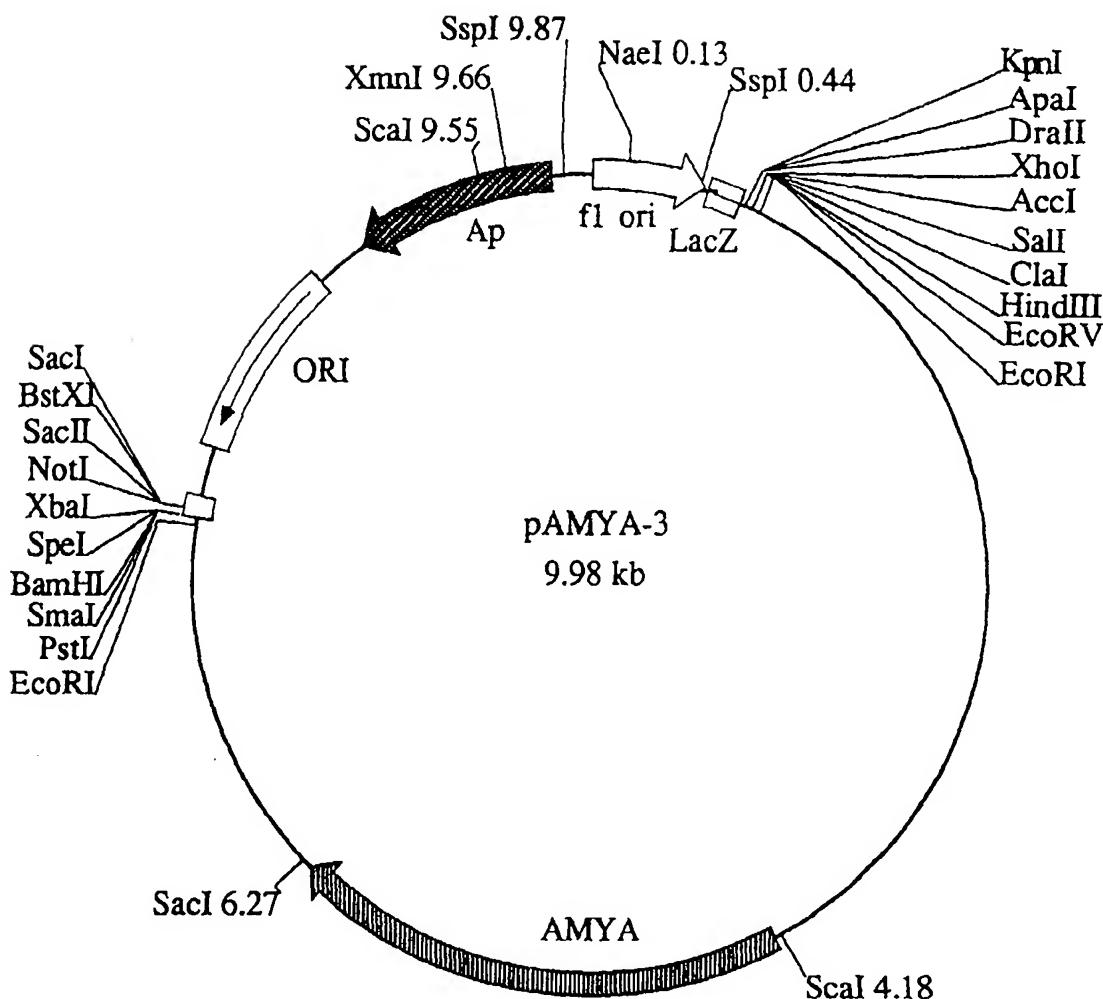
Constructed by: PR, JR

Construction date: 15/3 1993

Comments: Made by *in vivo* excision of an ZAPII phage

Fig 2

3 / 9



Plasmid name: pAMYA-3

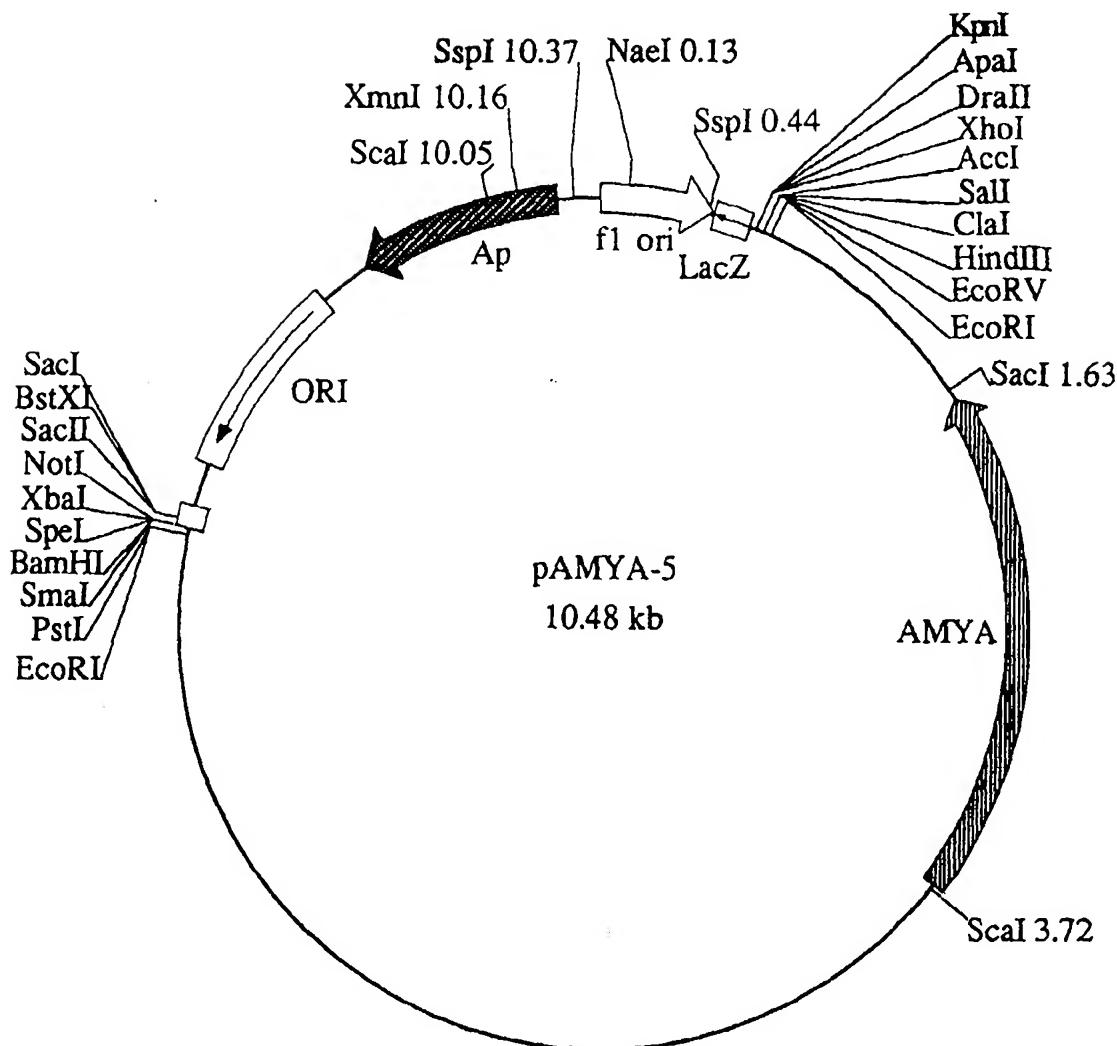
Plasmid size: 9.98 kb

Constructed by: PR, JR

Construction date: 15/3 1993

Comments: Made by *in vivo* excision of an ZAPII phage

Figure 3



Plasmid name: pAMYA-5

Plasmid size: 10.48 kb

Constructed by: PR, JR

Construction date: 15/3 1993

Comments: Made by *in vivo* excision of a ZAPII phage

Fig 4

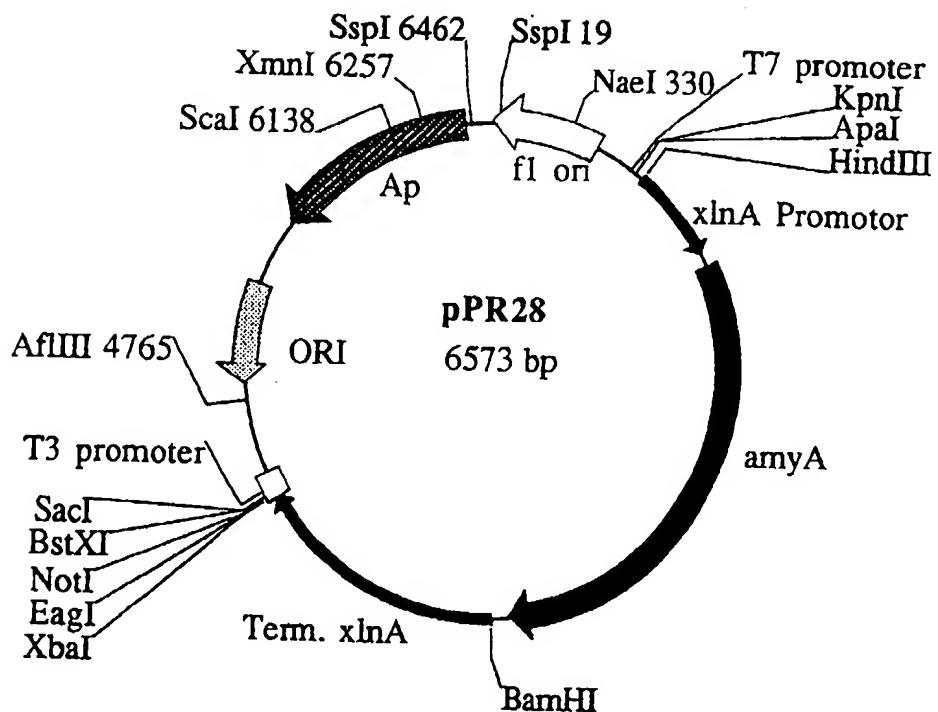


Fig 5

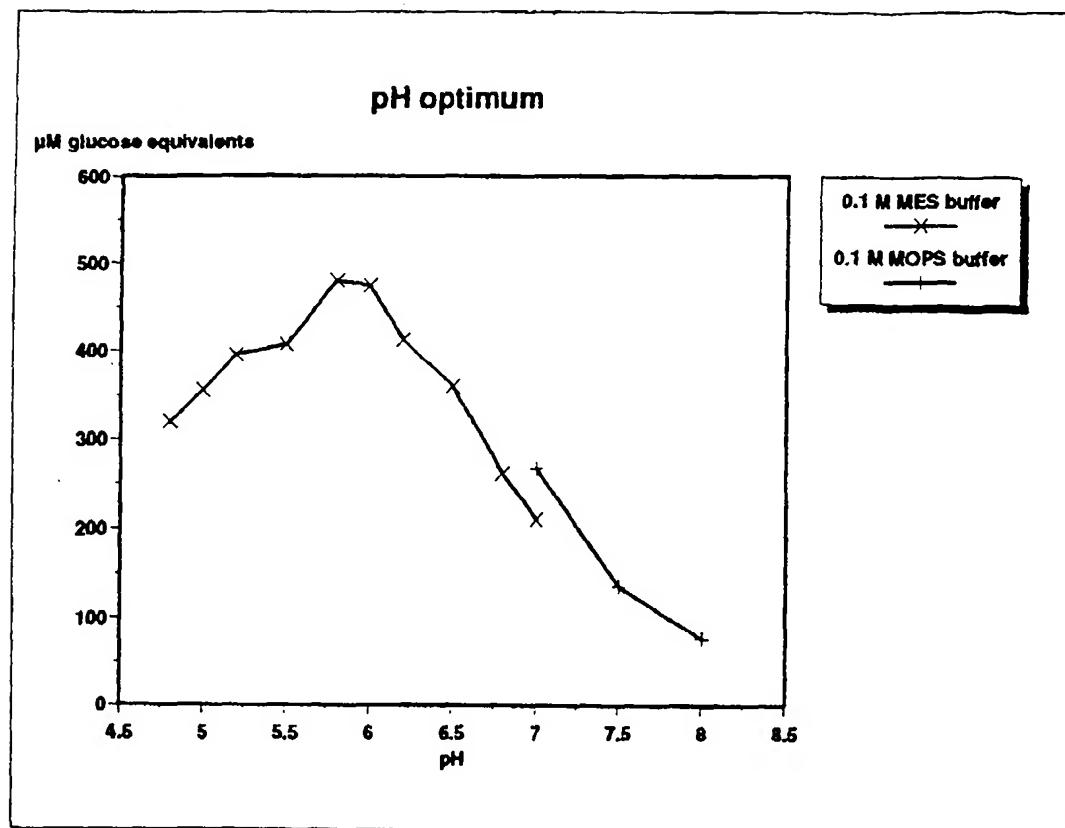


Fig 6

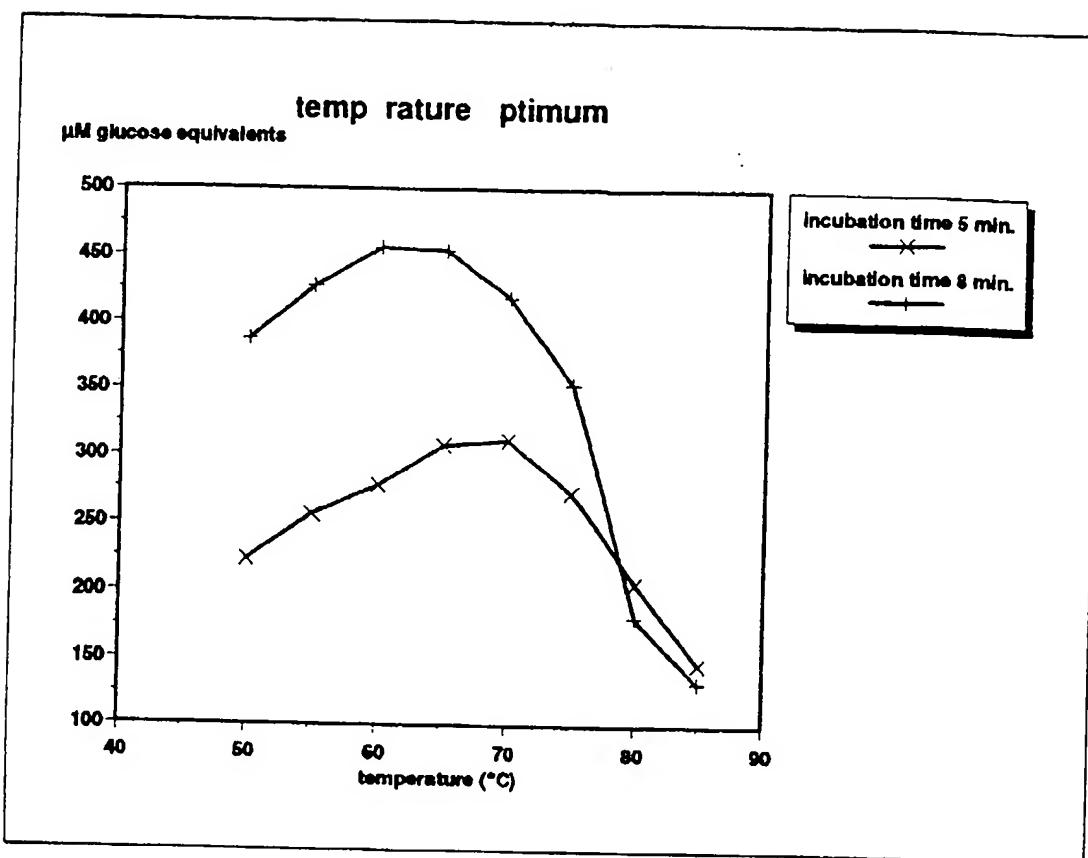


Fig 7

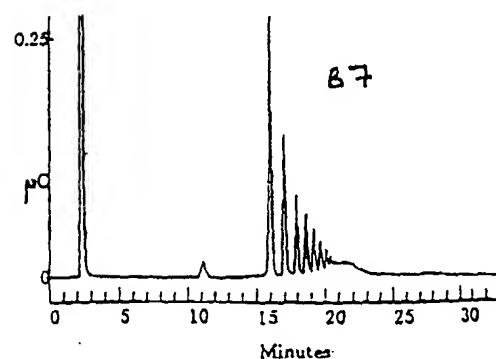
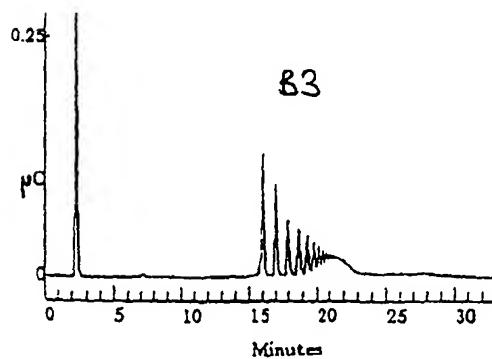
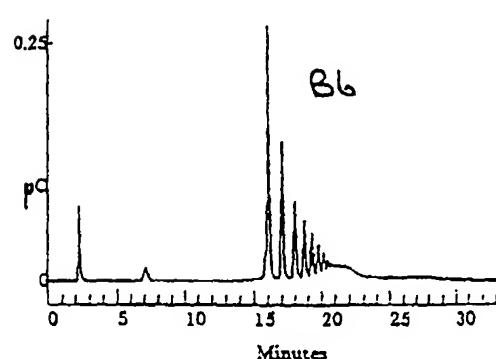
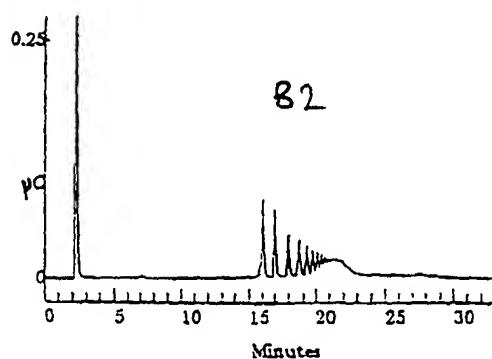
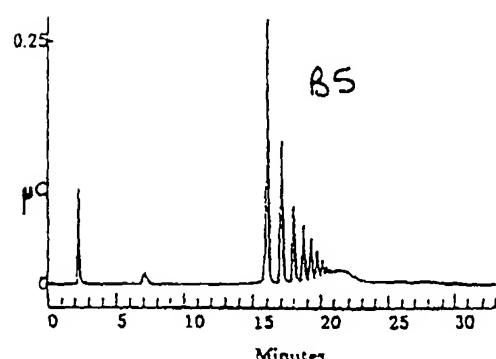
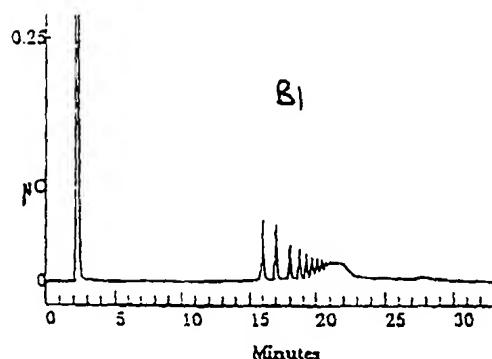
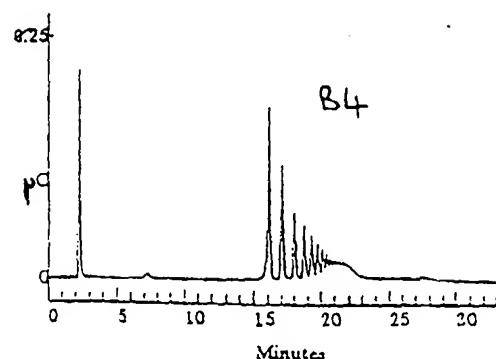
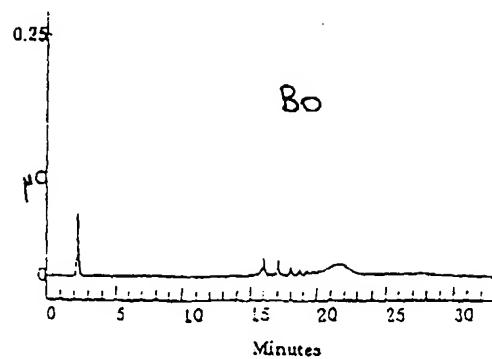


Fig 8

SUBSTITUTE SHEET (RULE 26)

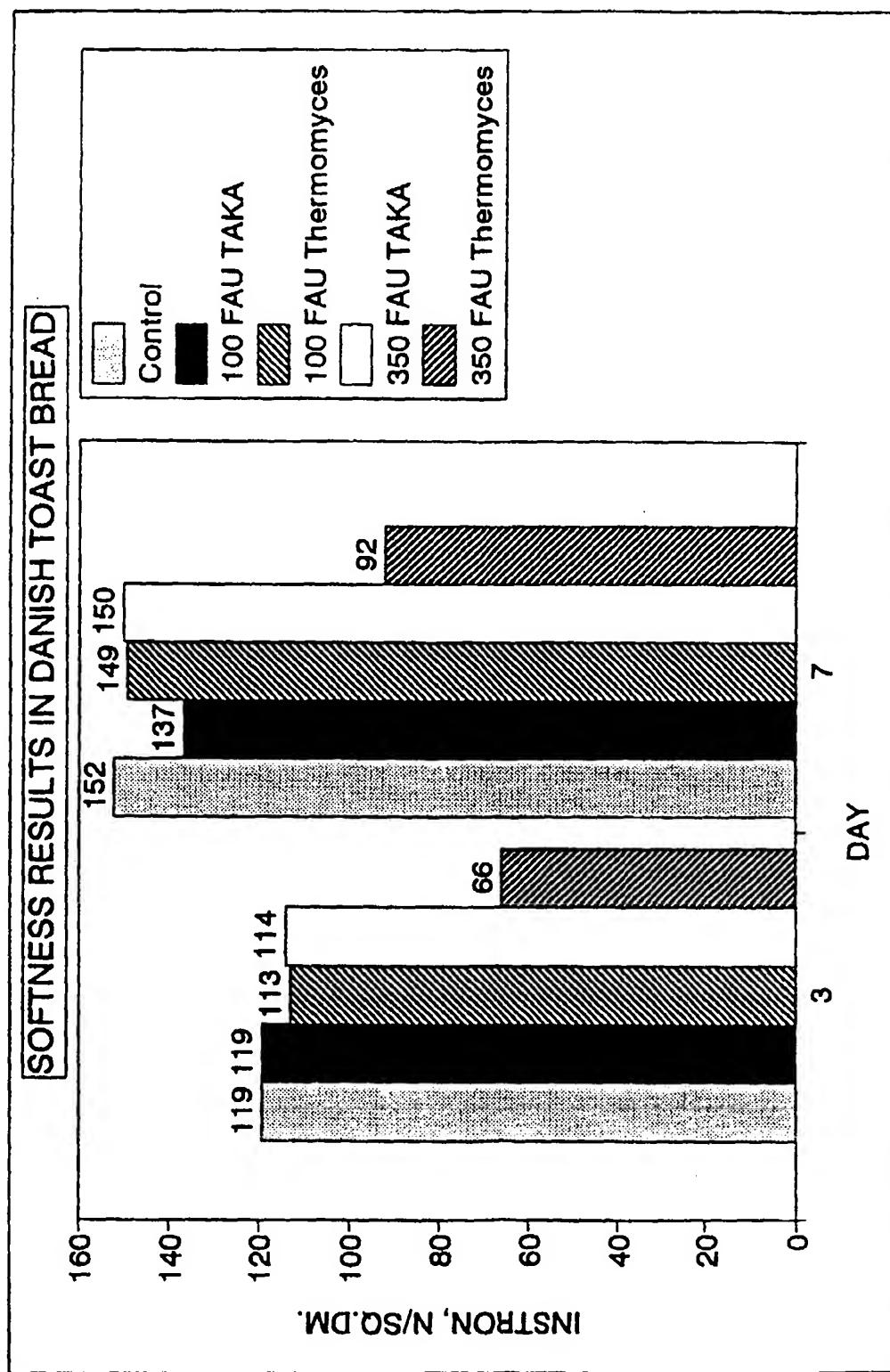


Fig 9

A. CLASSIFICATION F SUBJECT MATTER  
IPC 6 C12N15/56 C12N1/15 A21D8/04 C12N9/30

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 C12N A21D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ENZYME MICROB TECHNOL 14 (2). 1992. 112-116. CODEN: EMTED2 ISSN: 0141-0229, JENSEN B ET AL 'PHYSICOCHEMICAL PROPERTIES OF A PURIFIED ALPHA AMYLASE FROM THE THERMOPHILIC FUNGUS THERMOMYCES -LANUGINOSUS.' see the whole document ---	1-17
Y	US,A,4 416 903 (COLE MORTON S) 22 November 1983 see the whole document ---	18-27
Y	US,A,4 416 903 (COLE MORTON S) 22 November 1983 see the whole document ---	18-27
Y	EP,A,0 273 268 (ENZYME BIO SYSTEMS LTD) 6 July 1988 see the whole document ---	18-27
		-/-

 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

## \* Special categories of cited documents :

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Date of the actual completion of the international search

Date of mailing of the international search report

26 October 1995

05.12.95

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## Authorized officer

Van der Schaaf, C

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 95/02607

## C(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP,A,0 419 907 (ENZYME BIO SYSTEMS LTD) 3 April 1991 see the whole document ----	18-27
A	EP,A,0 238 023 (NOVO INDUSTRI AS) 23 September 1987 see the whole document -----	1-17

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		JP-A-	63301789	08-12-88
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		AU-B-	633138	21-01-93
		AU-B-	6241890	21-03-91
		CA-A-	2025123	14-03-91
		DE-T-	69002572	25-11-93
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		IE-B-	63138	22-03-95
		JP-A-	3155742	03-07-91
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		DK-B-	169134	22-08-94
		EP-A-	0489718	10-06-92
		ES-T-	2061446	16-12-94
		IE-B-	63169	22-03-95
		JP-A-	7051067	28-02-95
		JP-B-	6065316	24-08-94
		JP-A-	62272988	27-11-87